ENGINEERING NOTES.

ENGINEERING NOTES.

BY

FRANK ROBERTSON, F.R. ASTRON. SOC.,
LATE FIRST LIEUTENANT ROYAL ENGINEERS,
AND CIVIL ENGINEER PUBLIC WORKS DEPARTMENT IN INDIA.

LONDON:
E. & F. N. SPON, 48, CHARING CROSS.
NEW YORK:
446, BROOME STREET.
1873.

ENGINEERING NOTES,

Dedicated

TO

THE SECRETARY TO GOVERNMENT IN THE PUBLIC WORKS DEPARTMENT.

PREFACE.

Originality in Engineering notes is out of the question; moreover, the best works extant on the subject appear to have borrowed so largely from the same source, or from each other, that it is next to impossible mentioning authorities.

The object of this work is to supply an exhaustive *digest* of *all* that is known on each subject so far as is necessary and sufficient for an Engineer in practice; the Alphabetical Index will enable him at once to arrive at what he wants without wading through irrelevant matter.

The detached form of unconnected paragraphs has been adopted to combine succinctness with perspicuity unattainable by a more discursive style.

The XIV. and XV. Chapters may call for so much remark as introduces each; "*qui s'excuse s'accuse*"; they should furnish their own apology for insertion, but few acquainted with Indian necessities will think either superfluous.

Instead of mere generalities, or irreducible infinite algebraic series, and formulæ to be developed only by one possessing an intimate knowledge of the differential and integral calculus and the higher branches of mathematical analysis, as far as possible, *actual dimensions* and scantlings are given, which may safely be used as of undoubted authority under their respective circumstances, and will serve therefore as standpoints to be adopted or improved upon.

The matters are unavoidably *grouped*, it being im-

practicable to keep each in a separate Chapter where there is such strong affinity either in the nature or purpose served; thus cognate works overlap and cannot be separated by any line of demarcation so clearly defined as to admit of studying one completely without introducing its neighbour.

Thus channels, banks, roads, bridges, masonry, brick-work, tiles, flooring, roofing, timber, carpentry, joints, fastenings, beams, girders, ironwork and machinery, locomotives, railroads, cuttings, earthworks, &c., cannot be completely isolated either in study or in practice.

Details about the construction of such things as the Engineer usually purchases in the market ready-made are avoided, or only so far given as use manifestly dictates.

The dimensions are neither absolute nor invariable, any more than the prices and rates, but anyone conversant with the disastrous results of building by rule of thumb, and the terrible waste incurred by the other extreme of disregarding proper rules and securing strength by massive overload, will recognize the advantage of having a handy average for immediate reference, even should prices alter or requirements vary.

In the hope of doing good by placing immediate information on all practical points at disposal by merely consulting the Alphabetical Index which supplements this work, and so being of use to the service in which he has had the honour of holding a commission, these notes are offered by the Author.

PARKWOOD, TORQUAY, DEVONSHIRE.

CONTENTS.

ENGINEERING NOTES.

CHAPTER I.

Arches, Bridges, and Aqueducts.

1. **Arch stones** are called **voussoirs**; they press against each other at surfaces called **bed joints,** which should be perpendicular to the intrados and faces of the arch.

2. The **extrados** may be either a curved surface or built in steps.

3. **Abutments** are the supports at each end of an arch; **piers** are supports intermediate between two adjacent arches; an **abutment pier** is an extra thick pier, to act temporarily as an abutment where the work has been left incomplete for any reason.

4. The **course** from which an arch springs is called the **springing course,** or **skew back,** according as its upper and lower beds are parallel or inclined to each other.

5. The up and down stream surfaces of an arch are called its **faces**; the under surface is the **intrados** and the exterior or back of the arch is the **extrados**; the portion between two adjacent arches, over the pier, is called the **spandril.**

6. **External spandril walls** are built over the faces of the arch parallel to its span, and may be (two feet) 2′ thick; internal **spandril walls** may be built parallel to them, and the intervals either arched or flagged with

stone or flat tiles; these intervals are called **spandril pockets** and must be **drained.**

7. Masonry for arches should be either **ashlar** or **block in course,** the beds all perpendicular to the thrust of the arch ring, and the **side joints** vertical and parallel to the faces of the arch. (IX., 29, 59.)

8. Bed joints must be thin and close, either built dry and **grouted,** or sheets of lead laid between to distribute pressure.

9. Masonry behind the extrados is called **backing. Backing** must be **block in course, coursed rubble, random rubble,** or **concrete,** and is very commonly carried up to **one-third** of the rise of the arch above the spring.

10. When the backs of the **voussoirs** constituting the **extrados** are built in steps, the **backing** should be in **courses** flush with the steps, or in radiating courses whose beds are prolongations of the beds of the voussoirs, or in a combination of both of these constructions.

11. Brick arches may be built of gauged bricks, that is, wedge-formed bricks, so moulded or rubbed to suit the radius of the arch. Brick arches may also be built of ordinary bricks, making the lower joints finer than the upper and outer, or driving slate into the latter to widen them.

12. Brick arches may be built in concentric half-brick rings, in fact **all stretchers** (II., 99), or in alternate **headers** and **stretchers,** that is laid edgeways and endways alternately; or with headers at such intervals that the interval of (n) thicknesses in the lower course of stretchers may exactly correspond with the interval of ($n + 1$) thicknesses in the upper course; or again the upper ring may have **all** its joints thickened with slate, so that the interval of, n, stretchers below may corre-

spond exactly with the interval of, *n*, stretchers above; this latter method is best for arches with long radius.

13. All the masonry or brickwork in an arch should be covered with a layer of **clay puddle, mixed cement,** or **bituminous concrete,** to keep it dry; rain water drains down this layer to the spandril valley, and is carried off by iron pipes through the haunches.

14. **Hoop-iron bond** may be very advantageously used in arching, and may be laid **round** the arch between the half-brick rings, or **longitudinally** along the courses, or **radially**; when laid radially it may be bent and carried back into the bed joints of the backing and spandrils.

15. If a **straight line** be drawn through each bed joint of an arch representing the position and direction of the forces at that point, a **polygon** will be formed, whose angles will lie one in each **voussoir,** and this polygon may be considered to have each angle loaded with the voussoir and its superincumbent mass.

16. A **curve** inscribed in the above polygon shows the **linear arch** or line of pressures, in its ultimate form when the voussoirs are infinite in number and indefinitely thin.

17. The **point** where the linear arch cuts a bed joint is called a **centre of resistance.**

18. The **centre of resistance** should lie within the middle third of the depth of the voussoir's bed joint.

19. The **stability** therefore of an arch is secure if a linear arch, balanced under the same pressures, could be drawn within the middle third of its depth.

20. The calculations are very complex, but may be found given *in extenso*, Rankine's 'Civil Engineering,' pp. 202–218 and 416–430; the necessity for calculation is altogether obviated by using Robertson's "**Tables**

for Arches," published by Spon, 48, Charing Cross, London.

21. Tie walls may be inserted for the sake of stability at right angles between the spandril walls.

22. The depth of the **keystone** of an arch is thus found; let r be the radius of curvature in feet at the crown of the **arch**; d, the depth of keystone in feet.

$$d = \sqrt{0 \cdot 12 \times r} \text{ for a single arch, or}$$
$$d = \sqrt{0 \cdot 17 \times r} \text{ for an arch in a series.}$$

23. Abutments should always have **pockets** in them to lighten the mass. These pockets may occupy about $\frac{1}{3}$ (one-third) of the whole volume of the abutment. By these hollows no strength is lost, and much material saved.

24. The use of **theory** in these matters is to compare rules with practice, and hence deduce safe conclusions within limits, also to avert the danger of copying good and bad models alike, and calling the result experience; in fact, its use is to economize experience.

25. The **thickness** of an abutment may be from $\frac{1}{3}$ to $\frac{1}{5}$ the radius of curvature at the crown of the arch.

26. The **rise** of an arch depends on the height available between spring of the arch and the roadway; from $\frac{1}{4}$ to $\frac{1}{7}$ is allowable, but $\frac{1}{5}$ is most usual where there is any chance of inferior work.

27. Thickness of **arch ring** might be only 18″ up to a span of 36′ with an increase of 1″ per foot of span; but for safety, with uncertain workmanship and materials, it is better to allow for

10′ span	to	20′ span	.. ..	1′ thickness of ring.	
20′	,,	30′ ,,	.. ..	2′	,,
30′	,,	50′ ,,	.. ..	3′	,,
50′	,,	70′ ,,	.. ..	4′	,,
70′	,,	100′ ,,	.. ..	5′	,,

Where work is inferior, not less than 2′ thick, however.

28. **Thickness of piers** may be from $\frac{1}{4}$ to $\frac{1}{10}$ of the span, say, $\frac{1}{6}$ of the span.

29. **Abutments** and **piers** are more elegant and quite as strong if made to taper slightly.

30. **Piers** are advantageously lightened like abutments by having pockets made in them, slabbed, corbelled, or cross arched over, and inverted arch bases, or else being built in parallel **deep ribs,** with thinner portions between them.

31. In **buried arches,** such as **culverts** and **tunnels,** an ellipse is the appropriate linear arch, and

$$\frac{\text{Horizontal semi-axis}}{\text{Vertical semi-axis}} = \sqrt{\frac{\text{Horizontal pressure}}{\text{Vertical pressure}}} = c.$$

$$c = \sqrt{\frac{p\,y}{p\,x}} = \sqrt{\left(\frac{1 - \sin.\,\varphi}{1 + \sin.\,\varphi}\right)};\ \varphi,\ \text{being the angle of repose.}$$

32. If an arch be designed correctly for **stability** it will have a slight surplusage of **strength.**

33. The best **site** for a bridge is at right angles to the current in a long straight reach of the river, where the banks are sound and steep.

34. The **piers** must never be thicker than is necessary for stability, say, $\frac{1}{5}$ to $\frac{1}{6}$ of span, as it diminishes the waterway and causes scour.

35. The **crown** of the lowest arch to be not less than 3′ above the **flood level.**

36. The **form** of arch which gives the greatest waterway, *cæteris paribus,* is the hydrostatic arch.

37. The adjacent land should be traversed by **embanked approaches** if liable to be flooded, or by a **viaduct** if there is any current upon it.

38. **Ice breakers** are up-stream projections, at an angle of 45°, made of a single strut placed beam

14″×10″, covered with sheet iron. The flat sheets of ice float up this and break across by their own weight.

39. When an arch is so correctly formed that it will stand without friction or cement, it is said to be in equilibrium.

40. The pressure which results in a state of equilibrium is called the **thrust** of the arch.

41. In a **semicircular** arch **unloaded** the tendency would be for the crown to fall in and thrust the haunches apart: in a similar arch **loaded flush** with the crown, the haunches would fall in and thrust the crown upwards.

42. The greatest danger to a **high arch** is from overloading the haunches; this decreases as the arch is flattened by lowering the crown.

43. The actual forces are ascertainable by the calculations indicated in Rankine's 'Civil Engineering,' pp. 202–220 and 416–430, they are, however, lengthy and complex; Robertson's "**Tables for Arches**' give all the results and pressures without any need for further calculation.

44. The **form** of curve suitable for arches is of the parabolic class.

45. A **circle** up to 60° of arc differs insensibly from a parabola; hence a circular arch is admissible up to 60° of arc, the **thrust** being everywhere tangential to the circumference.

46. A **segmental arch** of 60° gives a rise or versin of $\frac{1}{7}$ or $\frac{1}{8}$ of the span.

47. The dimensions in feet of an arch multiplied by the weight of a cubic foot give the **absolute weight.**

48. The **absolute weight** of a half arch multiplied into the cotangent of θ, gives the horizontal thrust, where θ is the angle the geometrical tangent at the spring of the arch makes with the horizon.

49. If W be the weight of the whole structure, $\frac{W}{2}$ is the weight of the half arch, and $\frac{W}{2} \times \cot. \theta$ is the horizontal thrust to be borne by the pier or abutment at each end of the arch.

50. Hence the **spring of the arch** should be kept as low as possible, to reduce the horizontal thrust; the construction of the piers will raise the water level slightly by their obstruction to the waterway, and the spring of the arch may be 3″ above the highest possible flood level.

51. The **flood level** is generally ascertainable by traces on the land, otherwise the evidence of the oldest inhabitants may be the only guide.

52. The **height** of the spring of the arch having been so determined, the next point is the height of the roadway: then calculate the thickness of the abutment **necessary** by taking moments about the heel of the structure, thus—

53. Horizontal thrust of loaded arch × height from the heel of the abutment to the spring of the arch = weight of the abutment × distance horizontally of the centre of gravity of the abutment from the heel + the vertical pressure of the half arch × its horizontal distance from the heel.

$$H \times h = W' \times x + \frac{W}{2} \times x';$$

where

H is the horizontal thrust of the arch.
h, the height of the abutment.
W′, the weight of the abutment.
x, the horizontal distance of the centre of gravity from the heel of the abutment.
$\frac{W}{2}$ = the weight of the half arch and its load.
x' = the horizontal distance from the spring of the lineal arch to the heel of the abutment.

54. The **thickness** so calculated **just suffices** for equilibrium, but **counterforts** equal to $\frac{1}{3}$ of the volume of such an abutment should be added.

More **diversity** is seen on this point than any other in constructive design amongst engineers.

55. Abutments may be carried up solid if necessary **above** the spring of the arch.

56. The **thrust** of an arch is enormously diminished by good cement; the actual thrust without cement, caused by arches in equilibrium, is given in Robertson's "**Tables for Arches,**" and hence the dimensions for the abutment may be at once deduced.

57. A **viaduct** pierced only at intervals is useful for traversing land liable to floods, without much current.

58. A thickness of $\frac{1}{5} \times$ span **was not sufficient** for an abutment pier to an arch 30′ span, 7′ rise, semi-elliptical shape, built in good masonry and cement: the pier was 11′ high and 6′ thick. $\frac{1}{3}$ of span is, however, safe.

59. If an arch were in perfect equilibrium, **theoretically** a pier 2′ thick would suffice for supporting two adjacent arches 200′ span each, and 2′ thick in the ring; such a pier would, however, be rickety and liable to crack; in **practice** $\frac{1}{5}$ to $\frac{1}{6}$ of the span is found safe.

60. Piers or **abutments** are improved by being built tapering or battered to the base, as the pyramidal form combines stability and strength with a clearer waterway for floods.

61. Piers should be provided with **cutwaters**, either straight, semicircular, or double quadrantal.

62. There are rules for turning circular arches into elliptical, but the rules are very arbitrary, and the simplest course is to take the offsets for the centering from Robertson's "**Tables**" direct. For the calculations, consult Moseley, Tate, Rankine, Wiebeking,

Professional Papers of the Royal Engineers, Aide Mémoire, &c.

63. One of the most **graceful arches** known is the semi-ellipse. Rise = $\frac{1}{6}$ of span, or rather less.

64. The **flatter** the **arch** is the more carefully should the **joints** be made, as the horizontal thrust increases enormously with the flatness if less than $\frac{1}{7}$ of span to the rise.

65. Depth of **keystone** by the best authorities varies between $\frac{1}{10}$ and $\frac{1}{47}$ × span, the average being about $\frac{1}{30}$ × span for large arches over 100′ span. The exact calculation is almost an impracticable problem from its complexity. (Rankine's 'Civil Engineering,' page 425.)

The depth of **keystone** may be

$\frac{1}{8}$	×	span for	spans up	to	10′.
$\frac{1}{10}$	×	"	"	"	20′.
$\frac{1}{15}$	×	"	"	"	30′.
$\frac{1}{18}$	×	"	"	"	50′.

Less than 2′ deep is not approved whatever the span may be, where the work is not thoroughly first rate.

66. Arches are commenced simultaneously at the two haunches and carried on equably to the centre, where exact space must be left for the single brick which does duty as **keystone.**

67. The **key** should be laid in finely ground morter and driven home by a few light taps with a mallet.

68. The **bed joints** all radiate from the centre of curvature.

69. When the span is 20′ or more, there is no **need to dress** each **brick** to the form of the arch, only to keep the bricks in actual contact at their lower edge, the upper edges being slightly open and the interstices well run with cement.

70. Unless **gauged bricks** are used, brick arches may

be bonded exactly like ordinary brickwork; it answers very well and is inexpensive to lay the bricks alternately on **end** and on **edge** in concentric **rings** from the haunches towards the centre, and the very same (but sideways, as it were) along the **courses,** from face to face of the bridge, thus giving lateral as well as vertical bond.

71. The most important constituent of a bridge is the **cement**; the best is made of one part stone lime to two parts fine pounded brick, the ingredients should be **mixed dry,** ground together under a grinding-stone, and then slaked with just sufficient water to make them into a paste.

72. Fine **gravel** may be used instead of pounded brick, the quality of the cement depends upon the lime being **slaked in contact** with the gravel or "soorki," from its caustic state. (See Chapter VI.)

73. The **spandril walls** may be at three-foot intervals if arched, and 1½′ to 2′ thick; if slabbed they may be at any intervals suited to the length of slabs procurable; the external spandril walls or **face** walls should be 2′ thick to resist the thrust of the spandril arches, or if very high 3′.

74. Bridges of **small span** on important thoroughfares should be the full width of the roadway.

75. Bridges of **large span** should not be less than 24 feet between the parapet walls.

76. No **approaches** should have a steeper gradient than 1 in 35.

77. On the **back** of the arch may be laid a single stratum of **brick on edge** in morter; over this again is spread a layer of loose metal 9″ deep, and beaten down to 6″ thick.

78. The structure must, like all others, be efficiently **drained,** by outlets through the parapet walls, or better

through the haunches, as they are less disfiguring in the latter situation.

79. The **roadway** must in all cases be protected by **parapet walls**, which may be 3′ to 5′ high, and $1\frac{1}{2}'$ to 2′ thick.

80. These **parapet walls** are in fact vertical continuations of the two external spandril walls, and should be prolonged and splayed outwards at each end of the bridge to form approaches; they are covered by **coping** weathered and throated.

81. The **position** or site of a bridge is determined by the line of road generally; and by local features, such as shape of banks, course and bed of river, specifically.

82. It is better to make **few and large** arches in general than many and small ones, as the **afflux** or **heading up** of the water is less in the former case.

83. **Parapet walls** should be plain panelled masonry, not balusters of pottery.

84. The arch itself should be **relieved** by **being projected** 4″ beyond the rest of the masonry about its face, else it will look like a hole in a wall; the face should for the same reason be chiselled into voussoirs or fillets.

85. Before commencing a bridge, ask the **highest flood level**, and test the information by flood marks, if any exist.

86. Make **three accurate sections** across the river's bed, one at the proposed site of the bridge, one a mile above, and one a mile below the site.

Take the difference of level or fall in inches, from the upper section to the lower one and call it *f*, inches.

Measure the **cross length** of the river bed on each of the three cross sections, add together and divide by three, this gives the **working border**. The sectional area of the water divided by the working border gives

the **hydraulic mean depth**; write it down also in inches and call it h, inches.

Then the **surface velocity** of the current will be

$$v = \sqrt{fh};$$

and the **mean velocity** measured in inches per second will be

$$\frac{9}{10} \times v = \frac{9\sqrt{fh}}{10}.$$

87. The safe **afflux**, or heading up of the water caused by the obstruction offered by the piers, can be best taken out from tables on the subject. (See No. 123.)

88. The **spots selected** for taking the three cross-sections should be average specimens, not exceptional forms of the river bed.

89. The utmost care should be taken that not a single brick is laid until it has been thoroughly **saturated** with **water**, else it will deposit a coat of sand from the cement, which cannot adhere to it. (II., 55.)

90. If **rubble** masonry be used for the **backing** of an arch and for haunches, it should be laid in courses, and every three courses be well grouted.

For further details see Brickwork, Masonry, Foundations, &c.

91. The radius of the arch is approximately for a rise of

$\frac{1}{4} \times$ span, $r = 0 \cdot 625 \times$ span.
$\frac{1}{5} \times$ span, $r = 0 \cdot 725 \times$ span.
$\frac{1}{6} \times$ span, $r = 0 \cdot 833 \times$ span.
$\frac{1}{7} \times$ span, $r = 0 \cdot 940 \times$ span.

92. The usual span for arches **over** railways is, if the line be narrow gauge,

Single line 16′ to 18′ span.
Double line 28′ to 30′ span.

93. Bridge is the **rule** and level crossing the exception: the engineer must be prepared to show cause for substituting a level crossing for a bridge.

94. Over bridges must have a **clear width** of roadway at least

35′ for a turnpike road		between parapet walls.
25′ „ carriage road		
12′ „ private road		

95. The **approaches** must be fenced 3′ high, and the parapets of over bridges must be 4′ high.

96. Under bridges, that is, bridges under the railway, must have the following minimum dimensions:—

	Clear Headroom.	For a Centre Breadth of	Height to Spring of Arch.
For a turnpike road ..	16′	12′	12′
„ public road	15′	10′	12′
„ private road ..	14′	9′	..

97. The approaches to a bridge are not to be **altered** to a steeper slope than

1 in 30 for a turnpike road.
1 in 20 for a public road.
1 in 16 for a private road.

98. As examples of **under bridges**, suppose—

	Span.	Rise.	Headroom.	Radius, Intrados.	Arch Ring.	Puddle Coating.	Permanent Way.	Total Height, Roadway to Rails.
Over a Turnpike Road ..	35′	4′ 6″	16′ 6″	36′·28	2′ 6″	0′ 6″	2′ 0	23′ 0
Over a Carriage Road ..	25′	3′·53	15′ 6″	23′ ·9	2′ 0″	0′·47	2′ 0	21′ 0

99. For an **over bridge**, clear headroom from rails to crown of arch = 16′; thickness of arch ring, 2′; puddle

coating, 0′ 6″; roadway, 1′: total height, rails to roadway, 19′ 6″.

100. An **iron girder bridge** over a railway should have a clear headroom of 14′ 6″ from the rails; the girder and roadway will be 2′ 6″ more; total height from rails to roadway, 17′ 0″. The **abutments** have upright faces and **battered** backs for girder bridges. (See VIII., 162.)

101. The **platform** of an iron girder **over bridge** may consist of transverse brick arches spanning across from girder to girder. In this construction the girders should be well tied together laterally. Or the **platform** may consist of cast-iron plates with stiffening ribs above, covered with **asphaltic concrete**: or it may consist of **buckled wrought-iron plates** covered with a layer of asphaltic concrete; the plate itself should be $\frac{1}{5}$ to $\frac{1}{4}$ of an inch thick for the covering of a platform, and $3' \times 3'$ to $3' \times 7'$ in length and breadth, with a **rise** of $\frac{1}{18}$ of the span $= 2''$.

102. Buckled wrought-iron plates have a longitudinal convexity in the middle and a fillet or rim round the edge; they are the best form yet devised for a **platform.**

103. The railway bridges have usually **abutments,** whose thickness is $\frac{1}{5}$ of span, backed by counterforts, whose volume is $\frac{1}{3}$ that of the abutments.

104. The **wing walls** are also **retaining** walls, and their base thickness may equal $\frac{1}{4}$ of height; their top thickness $\frac{1}{8}$ of height. The thickness may diminish in steps or **scarcements** at the back, which is vertical, say 6″ to every 4′ of height in high walls, or 6″ to every 5′ of height up to 15′ high. The face has a **batter** usually of 1 in 12. (III., 164.)

105. Much judgment is required to avoid long **approaches** to bridges, by keeping always to the minimum size of bridge, and by cleverly adjusted levels.

106. **Level crossings** are **cheaper** than bridges, but the public safety should determine the choice.

107. A **canal bridge** requires 10′ clear headroom on the towing path for a man on horseback, or say 12′ clear of rearing. The towing path is 6′ to 10′ wide.

108. A **canal bridge** may exclude the towing path, in which case the rope has to be cast loose.

109. **Canal bridges** may be made **movable** by turning about a **horizontal** axis, a **vertical** axis, like a gate; by **rolling** back and forwards; by **lifting** vertically; or by **floating**. In any case the greatest attention must be paid to the counterpoise weight.

110. If the bridge open **horizontally** like a door, it is called a **swing bridge**, and moves on a circular base plate with rollers, and a pivot in the centre, supported on a masonry or iron pier like a railway turntable.

111. A **movable bridge** revolving on a horizontal hinge is called a **drawbridge**; it is opened by a pinion and toothed sector, or by chains.

112. A **rolling bridge** rolls on a pair of rails, and requires a transverse **rolling frame** to complete the approach when shut.

113. A **lifting bridge** is hung at the four corners to four counterpoise weights by four chains over four pullies.

114. A **floating bridge** is on a caisson or pontoon, and swings into a recess on the canal side when open, by chains and a windlass.

115. **Suspension bridges** are peculiarly adapted for aqueducts, from the uniformity of the load.

116. The **horizontal distance** from edge of the canal trough to outer face of the spandril wall in a canal aqueduct may be on one side 4′+18″ for thickness of the spandril wall; on the other side 6′ to 10′ for towing path+1′ 6″ thickness of spandril wall.

117. Above **culverts**, and near retaining walls, or

wing walls of bridges, the earth should be spread in very **thin layers** and carefully rammed to avoid shocks; this should be done the entire interval between the wing walls of bridges, 10′ back from abutments of **culverts** or **bridges**, and half the height of the finished embankment **over** the **arches** of culverts; the remainder may be tipped in the usual way.

118. An **aqueduct** carries water as a viaduct carries a way. An **aqueduct bridge** differs in no respect from an ordinary bridge. The water channel is usually of the same material as the rest of the structure, but if **masonry** the water channel should be bedded in **clay puddle** or **concrete** to render it more secure.

119. A **tubular** wrought **iron aqueduct** may be made self-supporting.

120. The **pressure** on an **aqueduct bridge** being invariable for all loads, and free from vibration, the conditions of stability are more easily satisfied than for any other kind of bridge; hence **suspension bridges** are peculiarly adapted for aqueducts.

121. The **pressure of wind** must be taken into account, especially in high railway bridges.

122. For **timber** bridges and **centerings** see Chapter V.

123. A **heading up**, or **afflux** of 5″ in the water, gives a velocity of 5′ per second, and is the maximum which can be allowed, unless the foundation rest on rock.

124. **Inverts** may be turned under arches, but they are only suitable when protected from undermining action. Curtain walls or sheet piling may be added under the edges.

125. A **flooring** of **masonry** 4′ or 5′ thick may be built to give additional security to piers; such a flooring should run right through the arch, extending 20′ up stream and 20′ down stream beyond the piers, and, like

the inverts, the flooring should have **curtain walls** or rows of sheet piling a few feet deep under the edges.

126. Where **piles** are used to support the **thrust of an arch,** they should be driven not vertically but in the direction of the line of thrust. Such a manner of driving piles is difficult without a special machine for the purpose.

127. For **iron** bridges, and trusses, girders, &c., see Chapter VIII.

128. Rules for **thickness** at top, of brick **piers,** if the span of the arch is from

15′	to	30′	thickness is	$\frac{1}{6}$	of span
30′	„	60′	„	$\frac{1}{7}$	„
60′	„	100′	„	$\frac{1}{8}$	„

129. In a long **series** of arches every fifth pier should be an **abutment pier**; or if not liable to flood, it may be buttressed temporarily with brickwork in mud, and loaded to counteract the side pressure.

130. Piers higher than 6′ should have a straight **batter** of 1 in 12.

131. The **backing** is usually **sloped** from the height at the spring of the arch (No. 9) up to the crown, and when the walls are built over the spandrils, the haunches may be filled in with gravel, stone, shivers, or anything **except** sand or clay. (III. 5.)

132. The **spandril pockets** (No. 6) must be **drained** along the top of the piers; and the roadway itself by gutters within the parapet walls, or footpath curbs, if any; through 3″ iron pipes with a 2″ flange at the upper end built into the masonry through the crown of the arch.

133. The **blocking course** is a string course running horizontal over the top of the arch along the spandril walls and wing walls; it may be $\frac{1}{20}$ of the span in depth, and broad enough to project 9″ beyond the

parapet wall, **both** inside and outside; the outer projection should be **weathered** and **throated.** (IX. 56.)

134. The **foundation** of **wing walls** must be as deep as that of the **abutment,** if the soil is bad; otherwise steps may be built to suit the surface slope, always 3′ below the surface.

135. Wing walls may be in **length** once and a half the height of the roadway above the bed of the river; the earth between them must be **gradually** filled in as the walls are built up, else the earth will swell when wet and burst the walls out.

136. Ends of wing walls may be widened 6″ and finished as **pillars** or **newels.**

137. Inside the parapet wall is a **wheel guard** when there is no footpath; the wheel-guard may be 9″ wide, and 9″ high, of brick on edge, one corner rounded off in the mould.

138. Curb stones may be 2′ × 1′..6″ × 6″, laid on edge, the upper edge chiselled, ends hammer dressed, lower edge and back rough, face dressed; the stones are laid with upper edge 9″ above gutter, the lower edge 9″ below; against their faces, similar stones cut square with fine joints are laid sloping 3″ to form a water channel or gutter; all the joints are well flushed up with morter.

139. For the **roadway** on a **bridge** there should always be a layer of brick on edge, covered by metalling beaten down to 1′ at the crown, and 9″ at the sides, even if the road be not a metalled road.

140. A **footpath** may be 4′ wide on a bridge, and 3″ to 4″ above the roadway; the **gutter** should lead water right **beyond** the ends of the wing walls.

141. In **inspecting** an arch whilst the **centre** is being **struck,** a theodolite is used to detect any settlement; for small semicircular or segmental arches, a tape is

hooked on to a centre and passed round by the hand to ascertain if the voussoirs are truly in position; it is important that the **keystone** be placed truly at the crown, and this point should be carefully secured.

142. Bridge **parapets** may be of stone, with brick or stone **coping**, or of brick with ditto, but attention must be given to make the closures firm with gauged bricks, wedge-shaped, otherwise the corners will soon give way if merely made of brick on edge coping.

143. If a **parapet** be pierced with **corbelled** openings, the projection of the ends of bricks must not be more than 1½″ (II. 73), else the masonry above will crack. A projection of only 3″ has sufficed to completely crack a parapet otherwise well designed and built.

144. Coping may be of plaster, and flat or sloped, plain, or weathered and throated. (142.)

145. For **arches** over **doors** and **windows**, one whole brick (on end), flat arch, or two half-brick (on edge) rings suffice for small doors. Entrance **doors** 9′ wide, may have three half-brick rings, either semicircular or flat arch relieved, and ½-brick work below it in the arch head. 11′ spans may have 4 half-brick rings, the two lower flush with the wall face, and the two upper rings projected 1″ and 2″ from the wall; the whole might spring from a flat collar or string course, projected 2″ all round the necks of the piers, 6″ deep.

146. There is usually **no vertical bond** in door and window arches, but the rings are separate, consisting of bricks all on end or on edge, so that the only bond is in a direction **through** the arch.

147. The following models for **light parapets** are easily made, and applicable to most **open work**: lay 1 course of 3 stretchers end to end, on their middle 1 course of 3 headers side by side, on their middle 1 course of 1 stretcher, above it 2 courses of 1 header each,

on them 1 course of 1 stretcher, above it 1 course of 3 headers, on them 3 stretchers; this forms a pillar, and such pillars may be placed 4½″ apart at base, all along the parapet. Otherwise open work may be made by 1½-inch corbellings to any amount of variety. (XIII., 156, 164.)

148. It is stated in a standard work that **semicircular arches** have the **advantage** of exerting **no** horizontal **thrust** upon their piers. The truth is that semicircular arches proper, being from their shape incapable of transmitting a horizontal thrust to the piers, will infallibly fall in, unless loaded and propped into **equilibrium.** (No. 41.)

149. The **process** in actually **constructing** a large bridge may divide itself into:—

150. Boring, or sinking pits, to ascertain the nature and determine the depth of **foundations.**

151. Construction of **coffer-dams**: get the exact position for the dams, length of piles, and scantlings. It is frequently a good plan to dredge before the piles are driven if the current be not strong, and there is consequently no fear of the trench filling in again. **Brace** the gauge piles across and get on the **waling**; drive the sheeting home; pump out the water, or let it out at low tide through a sluice gate; lay and ram the puddling.

152. Drive **piles for foundations**, saw their heads off level, fill in between them with hand-packed rubble or brickwork, lay on the sleepers, fill in between them, and lay down the planking.

153. Prepare **traversing cranes** for erection of piers, to work on the sides of the coffer-dam, and mark the exact position of the centre line of the piers.

154. Commence stonework of the **piers**; fill in round the bases with hydraulic concrete or rubble masonry.

The abutments and piers should progress simultaneously, that no time may be lost. Work up to the spring of the arch, and lay the **skew backs** or spring stones.

155. While the piers are in course of construction, **centres** are being made, and voussoirs being cut. Adjust the heads of the **gauge piles** to receive and support the centering; lift the ribs of the centering into their places one by one, by means of the traversing cranes; lay on the **laggings** and prepare their surface to the true form of the arch, and mark thereon the courses of stone or brick.

156. Erect a **service bridge** for large traversers or span cranes.

157. Commence to turn the **arch** from **each end**; be careful to keep up the **backing** regularly; keep the joints of the spandrils high towards the arch, or leave them to be filled in after the centre has been slacked, which is better; carry the spandrils no higher than the backing at present.

158. After the arch has been **keyed, ease** the **centres** evenly, and when daylight is seen between them and the soffit of the arch, proceed with the spandrils, spandril walls, and complete all for the roadway.

159. The **centres** not to be **struck** until the bridge is **ready** for the **roadway.**

160. The **coffer-dams** are prepared for removal as soon as the piers are above high-water level; having struck and removed the centres and service bridge, the waling is taken off the coffer-dams, the sheeting and then the gauge piles are drawn and the dam removed. Dredging out the puddle is a tedious operation, and in strong rivers it may be left to be washed away by the current.

161. It is **most important** for the stability of an arch that the **voussoir joints** or radiating joints of the

archway be **normal** to the curve. In order to ensure this approximately, use a gauge rod 3′ long, with a perpendicular fixed to its side. The gauge rod is applied to the soffit, and the perpendicular shows the proper inclination of the joint, or radii may be laid off from the centre found by (No. 91), their prolongations give the joints.

162. The **arches** of a **building** should not be begun until the morter of the piers or walls supporting them is thoroughly set.

163. Where the method of **concentric half-brick rings** is inapplicable, as in spans over 30′, the rings may be in lengths of $\frac{1}{5}$ of the span interrupted by whole-depth **blocks** of ordinary **bonded brickwork**, the bricks being moulded, scabbled, or wedged to gauge.

164. **Inverts** as a rule are made much too flat. Their proper form is indicated sufficiently nearly by the curves for a horizontal load at 20′ depth in Robertson's "**Tables for Arches.**"

165. A substantial **centering** for either domes or arches may be constructed of pillars of **brick in mud** covered by rough timbers, upon which again similar brickwork is built up to the soffit of the intended arch or dome; this is plastered with **soorki** and cowdung to the exact shape of the soffit as shown by a wooden gauge frame.

166. Small **holes** must be left in the **centering** to carry off the **water** with which the dome is flooded whilst in course of construction.

167. **A dome centering** if of brick in mud allows its **materials** to be **used again**, in the **flooring** for instance, when all the work has thoroughly settled. Otherwise the dome may be built on **laggings** of 2″ × 2″ laths or bamboos resting on the **ribs**, whose upper edges are planed to the necessary curve, and which are

strutted up from **sills** supported by brick in mud **pillars** or wooden posts.

168. Wide **planking** must not be used for **laggings** in India, as it is apt to warp.

169. Domes must be carried on equally all round from their haunches. The best curve is not hemispherical, but such as is given on page 66 of Robertson's "**Tables for Arches.**" If for a mere roof, regardless of profile **beauty**, the curves given on page 60 or 61 of the same Tables will serve the turn.

170. The **space left** for **keying** may be somewhat less than is required for the last brick or two bricks forming the key; into this space two planks may be inserted and wedges driven in between to open out the key interval and pack the neighbouring joints firm together.

171. The **centering** may remain up till the brickwork is **slightly dried**, and then be cautiously removed.

172. Arched **roofs** and domes are all the better for being **exposed** one rainy season **without** plaster, which can afterwards be added to the seasoned roof.

173. Small **holes** 6″ or 9″ diameter are to be left for **ventilation** through the crown of arched roofs; they may be protected from the weather by tubes of baked clay or a cover of masonry, as for chimneys.

174. Syrian tile roofs and Sindh roofs both require specially constructed **hollow voussoirs**; they are light and easily constructed, as well as cheap. Two bricklayers in two days have roofed a room 22′ × 18′ with the Sindh voussoirs.

175. In arching with the Sindh voussoirs, the order of laying them must be preserved ('Roorkee Treatise,' vol. i., page 274). The only cement necessary is mud and chopped straw. The whole is plastered with mud on the outside.

CHAPTER II.

BRICKS AND BRICKWORK.

1. Bricks are made of clay (silicate of alumina); if silicates of iron, potash, soda, lime, magnesia, &c., be also present so much the better, as the clay will be more fusible; without certain proportions of one or more of them the clay will be refractory and more suitable for **fire-bricks** and **crucibles**.

2. Clay and sand form **loam** when mixed.

3. Clay and a **small quantity** of carbonate of **lime** mechanically mixed form **marl**, from which **malms** are made.

4. **Fire-clays.**

1 equivalent of alumina + 1 of silica = porcelain clay or kaolin.
" " 2 " = Stourbridge fireclay.

5. **Silicate of lime** renders clay too fusible.

6. **Carbonate of lime**, if present in the clay in quantity sufficient to effervesce with acids, turns into quicklime in the burning, and disintegrates the bricks.

7. **Sand** in the proportion of $\frac{1}{3}$ is good to mix with the clay; above $\frac{1}{3}$ of sand would make the bricks brittle, soft, and apt to fuse in burning.

8. **Brick-clay** should be dug in **autumn**, and heaped 2′ deep all through the winter; the depth of the heap is marked by gauge stakes driven in a level piece of ground.

9. The **tempering**, or poaching in the **pug-mill**, is the most important operation in brickmaking: half the volume of water is added to the clay, and the quality

of the brick depends greatly on the thoroughness of the **pugging.**

10. The brick **moulds** may be 10″ × 5″ × 3″ inside dimensions, and the bricks will shrink to 9″ × 4½″ × 2½″ in burning.

11. Bricks burnt in **clamps** are preferable to those burnt in **kilns.**

12. The **burning** in a **kiln** should be raised in 24 hours to a white heat, maintained there till the bricks are thoroughly burnt, and cooled: the whole process takes from 15 to 21 days, and the thicker the brick the more difficult it is to dry thoroughly before burning, or to burn thoroughly without vitrifying.

13. Three men and two boys form a **gang** for brick-making, and can make 16,000 bricks in a week.

14. The **fuel** used in burning a thousand bricks is from 5 to 10 cwt.

15. Bricks should be **thoroughly dried** in the open air, or in drying houses at 50° to 70° of Fahrenheit, before burning.

16. **Bricks** should have clean sharp edges, compact glassy structure, and ring well; a bluish-grey colour is good, shuffy unsound bricks should be rejected in all important works.

17. **Good bricks** should require 1100 lbs. pressure per square inch to crush them; if built into columns, 800 lbs. per square inch would be the crushing force: they begin to show signs of giving way at 400 lbs. pressure per square inch.

18. **Inferior bricks** may be estimated at half the above strength.

19. **Compressed bricks** are made by drying and grinding the clay to powder, moulding under a pressure of about 5 tons on the square inch, and baking in a pottery oven.

20. Stiff clay burnt in a kiln gives the **red** brick.

21. Yellow fat earth called **loam** (No. 2) burnt in a **clamp** gives a hard, durable, bluish-grey, sharp-edged brick, called the **grey stock.**

22. Light earth is unmanageable, and has too much sand in it for making good bricks.

23. Strong clay is improved by the addition of **sand**, which lessens shrinkage and prevents cracking in burning. (No. 7.)

24. The process of brickmaking is commenced by choosing a clean hard level piece of ground near the clay pits; pegging out a square on it large enough to contain all the clay for the bricks wanted, when heaped 2′ deep on the square base; cutting a number of 3′ stakes and driving them at intervals 1′ into the ground to act as 2′ gauges on the square base; stripping the turf and surface soil off, digging up the clay and spreading it 2′ deep on the square plat, where it is left all through the winter.

25. If the clay require **sand**, the sand may be added in **spring**, simply spreading it over the top of the clay-heap up to 6″ deep or less, as wanted. (108.)

26. Brickmaking proper must not be commenced until all danger from frost is over, say at the end of March, in England.

27. The heaped clay (and sand) is then tempered in a **pug-mill** 5′ high, 3′ diameter at bottom, and 2′ 6″ at top; this is better than treading the clay. The workman chops a portion vertically downwards with a shovel, turns it well over and adds a little water if wanted, he then wheels it to the **pug-mill** and upsets it in at the top; as the tempered clay comes out at the bottom it is wheeled to the **moulding shed**, where a boy sitting on the right of the moulder takes a piece large enough for a brick, works it up and rolls it to the

moulder, who lifts it up, dashes it into the mould, and presses it well into the corners, takes a straight edge (a **strike**) out of a bowl of water, strikes off the overplus clay with it and throws the overplus back to his assistant on the right, turns out the newly-moulded **green** brick upon a **brick-board** which slides down a double rail to the off-bearing barrow, dashes sand into the mould to prevent adhesion, and is ready for the next brick.

28. Two off-bearing barrows are wanted with light frames and flat tops for moving the bricks while **green**; the off-bearer must be a skilful man, else he will effectually spoil the moulder's work; he places the bricks, each lying upon its brick-board, on the barrow, sprinkles them with dry sand and wheels them down to the **hacks**, which should be between the moulding shed and the kiln or clamps. The **hacks** are banks 2′ wide at top, 5′ apart parallel to each other, and any convenient length, with perfectly smooth surfaces, sand is sifted over them and over the barrow track leading to them, to make the off-bearing barrow run smoothly. The off-bearer places a loose brick-board on the upper surface of a green brick, when moulded and sprinkled as above, then he lifts it between the upper and lower brick-board, places it on edge gently on the hack, returns its board to the barrow, takes and places another, and so on.

29. The **hacks** are two bricks wide, the bricks being placed slanting and pretty close together. When one bottom row is completed, another hack is commenced, the bricks being too soft to bear weight yet. The bricks being **set**, that is hard enough, they are piled up eight bricks high, in a few days they are reversed in more open order, the former top bricks being now placed at the bottom.

30. The hacks should be covered at night with **long**

straw (rye is best), but not be dried under sheds, as they feel the loss of the sun.

31. The bricks must be as dry inside throughout as outside before they are burnt, else they will fly to pieces in the burning.

32. An oblong kiln to burn 20,000 bricks will be $14' \times 10'$ inside, and $12'$ high, the walls three bricks thick, with a slight inclination inwards as they go up. The floor is of arches (not inverts), the fire is beneath, and comes up between the floor arches; the kiln has one aperture only for entrance to place the bricks, which are laid closer at the top and more open at the bottom to let the fire through. The whole is covered with old brick and tile rubbish to keep the heat in.

33. First some wood is put in and kindled to **dry** the bricks and **warm** the kiln. When the bricks are properly dried, this is known by the **smoke** becoming transparent; then, and not till then, the aperture is stopped up with **old bricks** and plastered with clay, leaving only room for a fagot to be inserted; fagots of brushwood, furze, heath, &c., are now pushed in, and the burning proper commenced, which is kept up until the arches look whitish and the flames begin to come out at the top of the kiln; it is now slackened a little, and alternately raised and slackened for 48 hours, by which time the bricks should have had enough.

34. Very great precaution is necessary to secure **thorough dryness** in the walls of a new kiln, else the heat will split them.

35. Too much sand makes bricks **shaky** or **shuffy**, like pie-crust.

36. Clamp bricks. Grey stocks.—To make **clamp bricks** a sandy earth is used, therefore no more is added in the operations; instead, therefore, of covering the heap with sand (25), coal or cinder ashes are laid on

the top, and, as above, mixed first by the shovel of the labourer, then thoroughly in the pug-mill.

37. The **sand** used by the **moulder** to prevent adhesion is, for kiln bricks, fine-grained **kitchen-floor** sand; that used for clamp bricks is Thames sand, silvery grain, and free from grit.

38. Clamp bricks require to be even more **thoroughly dried** than kiln bricks before burning, as the whole force of the fire is applied at once in a clamp.

39. The ground for the clamp is raised, levelled perfectly, and covered with old bricks **set on edge.** On these are placed the raw bricks on edge, with a space 9″ wide and 3′ high down the middle from end to end of the clamp to contain the fuel; if the clamp be large more such fuel spaces may be left.

40. Clamps must not be exposed to wind; boards, hurdles, straw, or reeds are sufficient shelter.

41. Cinders called **breeze** are sprinkled between the bricks, and layers of breeze are spread amongst them in the clamp.

42. The **flues** (in No. 39) are not arched over at 3′ high, merely corbelled up at the top (No. 73).

43. The **breeze** must be thickest at the sides of the clamp, and thinnest near the top, as the heat ascends.

44. The clamp is **topped** with dry earth or turfs, and the whole cased round with old slack-burnt bricks, called **place bricks.**

45. The **wood** in the **flues** is then lit, and when it gets head the flue ends are built up with old bricks set dry and plastered with clay.

46. **Breeze** is simply the result of a coal fire with the ashes screened out.

47. **Badly-burnt** clamp bricks are tender, and of a **pale red** colour; good grey stocks are, on the other hand, hard, sound, of an uniform yellowish-grey colour.

Too little fuel renders the bricks very inferior in quality; too much fuel **vitrifies** the bricks, running them together like melted glass.

48. **Vitrified** brick is like **black rock.** It may be used for foundations or for ornamental rock-work if the crowbar fails to disunite the mass.

49. In every clamp there will be some **place bricks,** or **burs,** as they are called, but a good clamp-builder will reduce the number to a minimum.

50. The **grey stock** is more durable, less porous, better in colour than the flaming kiln-burnt brick, and should consequently have the preference *cæteris paribus* in building.

51. By washing brick-earth and adding **chalk** thereto, the colour can be varied. Such bricks are called **malms,** and may be best malms (or rubbers), pickings, and seconds.

52. **Rubbed,** or gauged bricks are first cut to a truncated wedge shape with a brick-axe, then rubbed to gauge on a **grit stone.** They should be the best quality of brick, and are used for arches, door, and window reveals, &c.

53. The first point in the construction of brickwork is to **reject all** misshapen or unsound bricks.

54. **Vertical joints** must be perpendicular to the beds, and broken in coincidence as with masonry.

55. Each brick must be **well soaked** in water before being laid in morter; fifteen minutes suffices. (No. 65.)

56. **All joints** must be **flushed up solid** with morter not more than $\frac{1}{4}''$ thick, say four courses to the foot.

57. No **bats** must be used in brickwork except to make a closure for a corner or opening, and then **never less** than half a brick.

58. The proportion of **morter** to brick would be about 1 : 5 by measure.

59. The **bond** would depend upon the direction in which strength is most required: for a wall, ordinary **English bond** of alternate courses complete of headers and stretchers, or say one of headers to two of stretchers, would be best. For neatness, **Flemish bond**, consisting of alternate headers and stretchers in each course, is best. For a structure whose height is very great in comparison with its base, like a factory chimney, there might be four courses of stretchers to one of headers.

60. In **English** bond the joints must be very fine, because there are twice as many header joints as stretcher joints, and thick joints are apt to increase the difficulty in breaking joint neatly.

61. **Hoop-iron bond** may be very advantageously introduced, laid flat in the bed joints and bent 2″ down at the ends, the strips of iron should break joint also. The proportion in sectional area may be hoop iron : brickwork :: 1 : 300.

62. **String courses** may be introduced in brickwork, either of stone, as in masonry, or of **headers** entirely. (IX., 53, 55.)

63. Great care must be taken to keep the joints fine where **stone quoins**, &c., are introduced in brickwork, as the brick joints are so numerous compared with the stone joints.

64. The **standard** of brickwork is one and a half brick thick; a **rod** of such brickwork means $11\frac{1}{3}$ cub. yards = 306 cub. ft.: **measurement** should always be given in cub. feet, and rates given per 100 cub. feet; all local terms reduced to these.

65. Bricks will **absorb** $\frac{1}{16}$ their dry weight of **water**; and they take from 13 to 15 minutes to do so. This time is therefore long enough to saturate them. (No. I., 89.)

66. **Fat clays** contain too much **alumina**; they

shrink in drying, crack in burning, and are difficult to burn thoroughly. (No. 7.)

67. Red burnt bricks contain oxides of **iron**; if from 8 per cent. to say 10 per cent., they burn **blue** or blackish, and are very strong. **White bricks** contain **lime**, which is useful in **very** small quantities as a flux to the silica. **Dun** coloured bricks contain **iron** and **lime**. **Brown** bricks contain **magnesia**, **pale** red contain **iron** in excess.

68. Fresh burnt clay is better than stale for mixing with lime (VI., 4), as puzzolana: a pair of crushing stones 5′ diameter and 12″ to 15″ thick should be attached to each set of kilns; they work in a firmly-fixed iron trough and grind the broken brick to powder.

69. Brickwork in morter **weighs** 112 lbs. to the cub. foot.

70. The best **size** for bonding, burning, and all considerations is $11\frac{1}{2} \times 5\frac{1}{2} \times 2\frac{1}{2}$ inches, which would require a mould to be $12\frac{1}{2} \times 6 \times 2\frac{3}{4}$ inches.

71. One **moulder** can make from 800 to 1200 bricks per day; a complete gang consists of

	Rs.
6 moulders at per month Rs. 6	36
15 men at 5 Rs. + 7 at 4 Rs.	103
2 boys at Rs. 3	6
1 pair of bullocks at Rs. 15	15
Total Rupees	160

for 160,000 bricks, or rupees 1 per M.

72. If **green bricks** get soaked with rain they are useless afterwards (No. 27); hence bricks are never made in the rainy weather: in the hot weather bricks are ready to burn in three days; during the cold weather in India they require eight days to dry.

73. Kilns must have the **lower arches** very attentively laid else the bricks will fall in; a projection

of (I., 143) only $1\frac{1}{2}$ inch to each course, for five courses should suffice to span the arch from the two sides working inwards across the flues; the backing should be well laid up simultaneously.

74. The warming of the kiln (No. 33) requires three days and three nights; the actual burning, from 48 to 60 hours, cooling at least 15 days to 18 days.

75. When the **kiln is burnt** it looks at night from the top like a molten mass almost transparent, the workmen guess when the bricks are sufficiently burnt by the amount of sinking, for instance, 35 courses of brick will have shrunk 9″.

76. Slack-burnt bricks must only be used for **inside** work, where they will suffer no exposure or strain, otherwise they will crumble away.

77. A good **kiln** "Roorkee pattern," 31′ 6″ × 11′ × 6′ 6″ deep will burn 15,500 bricks 12″ × 6″ × $2\frac{1}{2}$ (No. 70), and turn out 81 to 93 per cent. of **first-class** bricks. In this kiln 575 maunds of dry wood are used for a burning.

78. The chief point is **regularity** in burning, if the intensity of the heat is intermitted the bricks will be **shuffy** like pie-crust. Each fire must have one man's constant attention, and the fireman should be changed every four hours: thus a kiln with ten flues requires 60 men and two gangers to attend to it.

79. A coal clamp of 100,000 bricks takes a month to burn; 650 to **700 maunds** of coal would be required, the bricks being laid in five courses, alternating with layers of coal 3″ or 4″ thick: sometimes a clamp takes eight or ten months to cool after it is burnt. A good clamp will turn out 80 to 85 per cent. of **first-class** bricks, that is, good for pucka work, but of these again only the best should be selected for arching.

80. Too much **fuel** must **not** be laid on the **upper**

tiers of a clamp, nor should the wood be **piled** with bricks before ignition.

81. Terra cotta is made of **clay** mixed with **ground glass** (broken bottles) and pottery ware; it is carefully sifted when ground, then mixed with a large quantity of water in tubs, worked about with spades and the ground glass or pottery ware added, the water is drained off and the clay passed through the pug-mill three times before moulding.

82. The time of **drying** over a gentle firing in the kiln is four or five days, and the actual **burning** takes four to five days longer, say drying and burning ten days altogether, and eight days to cool.

83. Common **proportions** for **ingredients** would be for **architecture,**

10	measures	clay	
4	"	crushed pottery (white)	
2	"	ground glass (broken bottles)	
2	"	white sand	addition of these is optional;
1	"	flint	

for **red flooring** tiles or bricks,

12	measures	red clay
5	"	sand
2	"	crushed pottery or vitrified brick;

for **roofing** tiles,

9	measures	of red clay
5	"	sand.

84. For **colouring** bricks and tiles they are heated on an iron table with a fire beneath till too hot to handle, then dipped for a few seconds into a box containing a thick creamy mixture of

4	parts	measured	of turpentine
1	"	"	litharge
4	"	"	boiled linseed oil
4	"	"	colouring matter.

The colouring matter is easily procurable in the

bazaar. For blue, ultramarine is used or else cobalt *laj*ward; black, manganese; green, copper; red, Indian red; yellow, salts of lead. After dipping, the hot bricks dry in a few minutes.

85. Terra cotta goods and **ornamental bricks** must be baked in a fire-brick **muffle** or complete shell, 4″ clear within the kiln walls at the sides, and 12″ short of the kiln roof at top; the bottom is arched with ribs every 6″ to strengthen it; the walls and top of the muffle are built of brick on edge, the fires are beneath it.

86. Brickwork is not so strong as masonry, but is generally cheaper.

87. The **scaffolding** consists essentially of upright poles, 30′ to 50′ long, called **standards,** across these **ledgers** are lashed level with the present height of the wall; on the wall and ledgers, at 7′ intervals, rest the **putlogs** which bear the planks. The standards may be 12′ or 14′ apart, and 5′ from the wall.

88. The ends of the **putlogs** which rest on the wall must **not** be **built** in, else their removal will disturb the masonry; their ends should rest on a **stretcher**, and as much as practicable occupy rather the space below windows and openings than the piers or solid portions of the building.

89. The **putlogs need** not touch the wall at all; they may be arranged to pass through the window openings and be supported inside the building.

90. In **repairing masonry** where there is a crack or junction, or where new work is to be connected with old, the adjoining ends should be **racked** back from each other, as it were in ascending steps, and the resulting wedge-shaped void subsequently built in.

91. Instead of building **kacha pacca masonry** and then plastering it, it would be a better bestowal of the morter to place it **between** the bricks to bind them.

D 2

92. Kacha walls in India are built of mud alone mixed with chopped straw; they will stand a good deal of wet and exposure if carefully made in the dry weather, but are apt to crack vertically.

93. Kacha brickwork means that constructed of sun-dried bricks laid in mud; it is allowable in **outhouses**, or **interior walls** of large buildings; it must neither be exposed to wet nor to a heavy weight.

94. Kacha pacca brickwork is built with sound, well-burnt bricks; the mud in which they are laid consists of clay and sand, mixed with water; a little chopped straw and cowdung should be added, and well worked up.

95. Hollow brick **walls** may be built of bricks which are moulded hollow, or they may be constructed of ordinary bricks so arranged in placing them as to leave hollow spaces piercing the wall vertically. The advantages presented by **hollow walls** are economy, lightness, and dryness.

96. All **returns, buttresses,** or **counterforts** are to be built **up with** the mains, and bonded properly to them, **not** joggled on afterwards.

97. No less than 24 cub. ft. of **morter** (dry) to be used to the 100 cub. ft. of **brickwork** when the bricks are $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$. The morter to be of the **tenacity** approved in the sample. More morter will be wanted if the bricks are smaller, less if larger; but the rates will not be altered on this account.

98. No **joint** is allowed to be more than $\frac{3}{8}''$ in first-class brickwork, or than $\frac{1}{2}''$ in **second-class brickwork.** For second-class brickwork the morter may be mixed in a trough, not ground together under edgestone; the bricks are **place bricks.**

99. Concentric rings should not be used for an arch (I., 12, 70) of more than 30′ span, lest the whole weight fall upon one half-brick ring, (I., 163.)

100. **Flooring tiles** are made of good clay with the addition of glass (No. 83) and broken crockery. A pattern is stamped upon this a quarter of an inch deep, and on the surface is laid a coat of

1 part clay		
1 „ ground flint or glass	}	mixed with water.
½ „ dry white lead		

The **pattern**, like the **moulding**, is given in plaster of Paris. The mixture for **coating** is laid on with a brush; its object is to prevent the colours from running or blending.

101. The various parts of the pattern are now filled in with clays prepared and coloured (No. 84) as may be wished; the tile is then dried and burned.

102. The **clay** for **tiles** requires to be much stronger than for bricks; the best generally underlies the brick clay. Blue clay is particularly good for tiles; very little sand is added, and **no** ashes, chopped straw, saw-dust, or any other foreign substance.

103. The clay is **dug** and **tempered** exactly as for bricks. Exposure to frost or heat improves it, and the tiles are moulded just as bricks are; but if with **raised edges** to catch or overlap, the **edges** must be worked out of the lump of clay itself, **not** stuck on afterwards.

104. The **tiles** are **dried** on **edge**, under fenced or walled **sheds** in the hot weather. The most common shapes are the pot cylinder, pantile, and Goodwyn's.

105. The objection to the **pantiles** and *S* tiles is that in attempting to **repair** one, so many more are cracked. They are generally laid in a bed of morter, on a framework of bamboos covered with matting.

106. **Goodwyn's tiles** are flat, and their adjacent edges may be covered by pantiles in morter, they themselves being laid in morter over a layer of flat

square bricks; this makes a rather heavy roof, but good.

107. The **pot cylinders** are made on a potter's wheel, and may be burnt in an open clamp with the flat tiles, using **dried cowdung** for fuel, which serves the purpose admirably, giving out a strong heat without fierce blazing.

108. The **larger** the tiles can be made the better. If the **clay** is very **stiff**, a little **sand** will be serviceable to render it plastic.

109. In **tempering** the clay, it may either be **pugged** in a mill, or watered and trodden by foot; the process of moulding is precisely similar to brick moulding (27), but the next day the new pantiles are laid across a saddle and bent gently over it, smoothing the back with the hand; the saddle must be sprinkled with ashes or brickdust to prevent adhesion.

110. An experienced moulder will form 300 pantiles per diem. The tiles then lie on the ground in stacks twenty deep for six hours, and when fit to be handled are carried off.

111. The **burning** may be effected in **kilns** to hold 30,000; a common shape is **circular.** The fuel may be all wood. The fire is gentle at first, till the disappearance of all white steam from the smoke, then it is raised till the flues appear red-hot, then slackened for six hours, then raised till the flues are white-hot and kept so three hours, again slackened for six hours, then raised to a white heat for four hours, flues filled up with fuel, their mouths stopped up with brick and mud, and the fires allowed to burn out. The burning generally takes altogether seventy-two hours.

112. In windy weather the kilns must be well **sheltered.** Any underburnt tiles must be placed on the top of the next kiln to be burnt over again.

113. The whole process of making and burning 30,000 tiles $9\frac{1}{2}'' \times 4\frac{1}{2}''$ might cost 67 to 70 rupees; this gives about 2 rupees 4 annas per M. The kiln is built of **brick in mud,** and will last three years if occasionally repaired.

114. The **loss** in making and burning should **never amount** to 10 per cent.

115. One **cubic yard** of clay will make 1060 **pantiles,** which are $10\frac{1}{2}'' \times 5\frac{1}{2}'' \times \frac{5}{8}''$ thick as moulded, or $9\frac{1}{2}'' \times 4\frac{1}{2}''$ when burnt.

116. The tiles will **crack in drying** if exposed to sun or wind.

117. Flat tiles are generally made $6\frac{1}{2}'' \times 5\frac{1}{2}'' \times \frac{5}{8}''$, being smaller than pantiles; 50,000 of them could be burnt in the same kiln (No. 111). Usually both are burned in the same kiln, the pantiles at bottom and flat tiles at top.

118. At the **School of Arts** in Madras, the proportions used for **brick** making are 3 parts clay to $1\frac{1}{2}$ sand; they used 3 of clay to 1 of sand for pipes. The clay can be trodden sufficiently in one morning. **Iron moulds** are found the best; the great point is to get up the heat **gradually** in burning. A kiln they used there was circular in plan, 6′ diameter inside, and 6′ clear interior height, with a 6′ dome above it, in which tiles are burnt simultaneously with the bricks below. The walls are 3′ thick. There are four fire-places opposite each other, with flues running right through; the fire-places project 1′ 6″ from the wall. Such a kiln burns 1700 bricks at a time.

119. Flooring tiles may be $12'' \times 12'' \times 1''$ or $2''$ thick; they should be laid in cement. Coloured and glazed, they form an excellent, cool, and clean floor. The best shape is quadrilateral or hexagonal, as these shapes will continuously fit together.

120. For **colouring tiles**, see (No. 84); the glaze is given by the addition of a flux (borax) which acts on the metallic oxides to form beautiful coloured glasses.

Oxide of	chrome	gives an	emerald green.
"	cobalt	"	intense blue.
"	copper	"	pale green.
"	tin	"	opal colour.
"	iron	"	bottle-green and yellow.
"	manganese	"	violet.

121. Drain tiles may be moulded **flat**, and bent to a curve round a **saddle** of wood (109), or forced by a piston through a die so as to exude under an enormous pressure in the form of a ready-made **pipe.**

122. Pipes are universally made now by such **machinery**; the clay is worked into a soft pulp with water in a tank by a long wooden spade; thence it is run off into a **lower level** tank, leaving any hard or heavy lumps at the bottom of the upper tank. After ten or twelve days' exposure to the sun, the clay is ready for use.

123. The **machine** consists essentially of a vertical iron-bound wooden cylinder 5′ 6″ long and 1′ 8″ diameter, strongly mounted on beams bedded in masonry. The wood is 3″ thick on the sides of the cylinder, and it is bound by four iron bands $\frac{1}{2}''$ thick. The piston is forced down by a strong wooden screw 8″ in diameter.

124. The **pipes**, as they are squeezed out by the piston under a **pressure** of nearly **10 tons**, are cut into 2′ lengths by a piece of thin wire stretched on a bow, and are dried in sheds.

125. One such **cylinder** full of clay contains twelve 8″-**pipes.** In this manner 250 to 300 can be made in one day. The pipes take five days to dry **under sheds**; if exposed, they will crack.

126. The **pipes** are burnt in **furnaces**, where they

are stacked upright as close as possible; they take 48 hours to burn thoroughly, the fires being gradually raised to a red heat and kept so for 12 hours, then to the greatest heat possible (that is, till the flame and the pipes are the same colour). This is kept up for 24 hours, when the whole is allowed gradually to cool.

127. The cost of each **2′-pipe,** $8\frac{1}{2}''$ or $6''$ diameter, was about 4 annas complete.

128. The pipes are made without sockets, as embedding them in lime sufficiently ensures the joints against leakage; but if wanted, **sockets** could easily be moulded on before the pipes are dry.

129. All **drain tiles** and **pipes** should be **glazed,** to prevent absorption.

130. Bricks, tiles, and **slabs** of **stone** are very commonly used in India as roof covering; they are simply laid on the joists, which might be $12''$ apart from centre to centre, so as to suit the $12''$ square tiles, or on burgahs $3'' \times 3''$, also laid $12''$ central distance apart. Over the tiles or slabs, which are finely jointed and pointed with lime morter to close all **seams,** is laid a layer of $3''$ to $6''$ earth, well beaten down wet; the earth should **not** be too **stiff** clay, else it will crack with the sun, nor too **sandy,** else it will let rain filter through.

131. Such a **roof** is called a katcha terrace roof in India. Instead of bricks, a bed of reeds or sticks may be laid on the rafters, tied together in small bundles and closely packed, on which again the earth may be laid and rammed wet.

132. A better **roof** at a greater outlay may be secured by laying an upper course of tiles over the lower so as to break joint, and plastering it with lime morter (packa terrace).

133. All such **roofs** should have a **slope** of $\frac{1}{2}''$ per foot to run off rain water. The slope may be given by

cambering up the **joists** below, or by laying the plaster **thicker** in the **middle** and sloping off to the sides.

134. Arching may be adopted for roofs, provided the horizontal thrust be neutralized by **tie rods** connecting the iron boiler-plates or timbers from which such an arch would have to spring. For the form of such arches see "**Robertson's Tables**" for arches, published by E. and F. N. Spon, 48, Charing Cross.

135. When such **iron plates** are used to support a thrust, the horizontal plate should be **outside,** not inside, else only half of the vertical plate can be made available to receive the thrust.

136. Whatever description of **tiles** be used for roof **covering,** a layer of **flat tiles** underneath them will add much to the coolness, and the upper **tiles** must **always** be laid in **morter** or cement $1\frac{1}{2}''$ thick.

137. In all **tiled** roofs, the **eaves** require to be very strongly made, generally covered with Chunam borders like the hips and ridges, otherwise the displacement of the tiles will be a constant source of trouble and expense.

138. For **Goodwyn's tiled roofing,** battens $3'' \times 2''$ may be nailed down to the purlins at $12''$ intervals from centre to centre; on these are laid square tiles $12'' \times 12'' \times 2''$ thick, well fitted and cemented at the joints and pointed underneath; a layer of good morter $1\frac{1}{2}''$ thick is then laid on, in which, while still soft, the pantiles are embedded at the proper intervals, which intervals are filled up with morter, the round tiles are fitted over them and set in morter; the roof may be watered for ten days by watering-pots from the ridge to prevent its drying too quickly in the hot weather.

139. Atkinson's tiled roofing consists in pantiles laid to cover the joints of flat tiles with edged borders which are laid on their backs in cement $1\frac{1}{2}''$ thick over

cylindrical tiles laid close on battens, like Goodwyn's (138) tiling.

140. The **pantiles** not to be less than ½″ thick and to overlap 3″ of the tile next below.

141. A good **thatch** is the coolest and driest roof; in order to make a thatched roof, a frame of small bamboos is made and laid upon the ground, it is like a trellis work with 6″ interstices, the bamboos being tied across each other with string: upon this a 3″ layer of grass is laid in small bundles and tied, then the frame and all is lifted into its place and the remainder of the grass tied on in bundles from the eaves working upwards, overlapping each other: the thatch should be kept up to 9″ thick, requiring a fresh coat 3″ or 4″ thick every three years.

CHAPTER III.

Banks, Dams, Earthwork, and Retaining Walls.

1. **Earthwork** is of two kinds, excavation and filling, or **cutting** and **embankment**; it may give way by falling apart or by sliding; the stability therefore of a bank depends upon the earth's **adhesion** and its friction.

2. The angle of **inclination** to the horizon at which earth will remain permanently, is called φ, its **angle of repose.**

3. The **angle of repose** φ, is as below for various soils:—

Sand φ	= 21°	or	2·63	to	1
Moist clay φ	= 45°	„	1·00	„	1
Wet clay φ	= 14°	„	4·00	„	1
Peat φ	= 14°	„	4·00	„	1
Shingle and gravel φ	= 35°	„	1·43	„	1

As a general rule for ordinary ground therefore, 2 of base to 1 of height is safe and sufficient.

4. The safest materials for earthwork are **shivers of rock**, shingle, gravel, and sand; all earthwork must be **well drained**, and this applies specially to sand, else it becomes quicksand.

5. The very **worst** material for earthwork is a mixture of sand and clay, or **loam**, because the clay keeps the water in, and the sand absorbs it.

6. A cubic foot of **earthwork weighs** from 89 lbs. to 120 lbs. according to its compactness.

7. The following **rocks** may be trusted **vertical** in cuttings when not fissured in a threatening direction;— granite, syenite, trap, gneiss, mica slate, marble, quartz.

Shale requires caution as it softens, after cutting, by exposure; sandstone and limestone if of such a quality as to be fit for building, will stand nearly vertical; experiment on the spot is the best guide, Tables on the subject are only useful as a guide to experiment.

8. The **mensuration** of earthwork is generally performed by the application of **Tables** according to the formulæ therein described.

9. A **half-breadth** of a cutting or embankment is the **horizontal distance** from the centre line of the formation or base to the end of the slope of the cutting or embankment, measured straight across the road; the two half-breadths may therefore often be unequal at the same place.

10. The **formation level** is the level of the bottom of cuttings or tops of embankments when finished, before the ballast or metalling is laid on.

11. A **hole** 4″ diameter should be **bored** previous to the commencement of a cutting, or, if important enough, a trial shaft should be sunk to ascertain the nature of the ground. In large cuttings both means should be combined, *viz.* a shaft at the point of greatest depth, and borings at every 300 yards along the centre line.

12. **Boring tools** are of wrought iron steeled at the end, in lengthening rods or joints 10′ long, ending with the borer itself about 3′ long, of which $1\frac{1}{2}'$ is the **auger** itself, and $1\frac{1}{2}'$ a square shank of $1\frac{1}{8}''$ side.

13. If the rock is too hard for the **auger**, which tool is $3\frac{1}{2}''$ diameter and works like a gimlet, the **worm** is used, a sharp-pointed spiral worked in a manner similar to the auger, with a **cross head** 6′ long, driven by two men always with the sun. Boring tools are finally extracted by shears and pulley, or a beam lever.

14. If the rock be too **hard** for auger or worm, a **jumper** and **scoop** may be used.

15. If the material be very **soft**, cast or wrought iron pipes screwed together may be used. Moss, mud, or quicksand may be probed by a **pricker**.

16. **Conjecture** and hearsay should be rigidly excluded from boring reports, else a lawsuit with the contractor may result.

17. **Equalizing** earthwork means adjusting the formation level so that the cuttings and embankments may balance as to Remblai and Deblai; else spoil banks must be formed or side cuttings increased, according as the one or the other is in excess.

18. **Temporary fencing** should be erected to enclose **all** the ground wanted, before the work is commenced; the breadth of the fencing is to be added to the width of the earthwork, or half-breadths of No. 9. **A hedge and ditch** is reckoned at 9′ width.

19. A good kind of **fence** is of posts and rails made of **larch** or **oak**: posts 6′ long × 6″ × 3″, of which 2′ 6″ to 3′ is in the ground ends charred, and the rails are 10′ long, 3″ deep, and 1½″ thick, scarfed into mortises cut in every second post, the posts are 4′ 6″ to 5′ apart.

20. **Catch-water drains** are made at the same time as the fencing on the upper side or on both sides of the earthwork.

21. In **draining** always **begin** at the lower end or outfall and work uphill.

22. **Catch-water** drains may be open ditches 4′ wide and 2′ to 3′ deep, or they may be of **stone** or brick, or earthenware tubes covered in with loose stone or gravel.

23. **Stripping the soil** of sods should be neatly done, that the sods may be used afterwards for slopes of embankments.

24. A **cutting** is commenced by making a vertical side **gullet,** wide enough for one or more lines of **earth wagons.**

25. The **gullet** is widened in steps or **lifts** 6′ or 8′ high, carried on simultaneously.

26. A drain called a **side drain** is wanted at the base of each slope of a cutting, the side drain may be 6″ to 2′ deep, open and made of stone, brick, or tubing, as in No. 22.

27. Besides the side drains **branch drains** should be formed, across the base and down the slopes. These branch drains, if of tubes, may be laid 2′ 6″ below the surface, and covered as usual with broken stone.

28. Springs of water, rising in cuttings, require special draining.

29. Earthwork is usually divided, as to **labour,** into **getting** or excavating, **filling** into barrows, **wheeling, loading** into wagons, and **teeming** or tipping over the end of the embankment.

30. Rock is cut according to its hardness by the pick, crowbar, wedges, or by **blasting.**

31. The **planks** for barrow wheeling should not be **steeper** than 1 in 12.

32. Leading is performed by **earth wagons,** No. 24, on horizontal trunnions for tipping over at the end of the lead.

33. One **excavator** can be told off for each 6′ of breadth of face, and 0½ to 2 **pick men** to each shoveller or excavator, according to the soil.

34. The expression "**Earth of** 2, 3, or **n men**" means that it requires 2, 3, or n **Shovellers and pick men** to keep one line of **wheelers** at work.

35. The **rate of advance** may be expected at 20 cub. yards of sand, or 16 cub. yards of clay per day for each line of wheelers.

36. Falling earth means undermining the mass, and then driving stakes above and behind it so as to throw it down.

37. An **earth wagon** holds 50 barrows.

38. Benches are levels 6′ wide on the sides of cuttings, to stop landslips and facilitate drainage. They should be provided with **side drains**. (See No. 26.)

39. If there is **much water** in a cutting, the **branch drains** (No. 27) should be frequent, and the **slope** may be faced with dry stone, laid 6″ to 1′ 6″ thick. The lower part of the slope may have trenches cut in it at right angles to the foot of the bank, and filled in with gravel or loose stone, these act as both **drains** and **counterforts**; or again, a base retaining wall may be built of dry stone, or of masonry or brickwork **backed** by dry stone.

40. After construction, **embankments settle** or subside from $\frac{1}{8}$ to $\frac{1}{12}$ of their original height. The amount must be ascertained and allowed for.

41. Embankments must be **supplied** from the nearest cuttings, and the **leads** or routes must not cross.

42. The **best materials** for embankments are as in No. 4; but **dry** clay is not bad; the **worst** materials are **wet** clay, vegetable mould, mud, and peat.

43. The best **method of construction** for embankments is in two or three or many thin layers 9″ to 1′ 6″ thick, well rammed, and lower in the middle than at the sides; in fact, concave surface as to cross section. (No. 176.)

44. No **tipping** over the **sides** should be allowed, only over the end of the embankment.

45. Sidelong ground must be cut into **steps** before embanking over it.

46. The earth must be spread in very **thin layers**, and **cautiously rammed** to avoid shocks, over **culverts**

(that is, covered drains of brickwork or masonry), near retaining walls, or wing walls of bridges. This should be done throughout the entire interval between the wing walls of bridges, 10 feet back from retaining or abutment walls, and half the height of the finished embankment over the arches of culverts; the remainder may be tipped in the usual way.

47. **Springs** should be avoided if possible, but if absolutely necessary to embank over a spring, a culvert should carry off its water.

48. An embankment in an **extensive plain** should have a flat surface, say 1′ to 4′ high, slopes, berms, and side trenches.

49. If the soil is **very bad, a foundation** may be dug for the embankment and filled in with stable material; or short piles and stakes may be driven in, either along the sides or throughout the width, to consolidate the soil; or again, the embankment may rest upon, or be made of, fascines, hurdles, or dry peat, so as to float upon the moss.

50. The **embankment** over Chat **Moss**, built by Stephenson for the Liverpool and Manchester Railway, consists of dry peat, two layers of hurdles, and ballast.

51. If these expedients fail, the only way left is to throw in **stones**, gravel, and sand till they **rise through** the moss. The angle of repose, φ, remains the same in moss as in air.

52. **Slopes**, when finished, are to be **dressed**, that is, made smooth and covered with 3″ to 6″ of soil, and sown with grass.

53. **Pitching** slopes means facing them with dry stone 12″ thick when exposed to still water.

54. **Clay puddle** is used to make embankments and channels water-tight. The clay should be free from stones, and must be well **poached**. It may have sand

in it to keep it from cracking, and even gravel is good; it is worked in **layers** 9″ thick.

55. Rock, if too hard for splitting by wedges, is blasted. The instruments used in blasting are the churn jumper, the borer, hammer, scoop, tamping rod, powder, and Bickford's patent fuze.

56. To find the proper size of the charge, powder in lbs. $= \frac{(l\,l\,r)^3}{32}$ for a small blast, that is, from 1″ to 6″ diameter and 1′ to 30′ deep, or say $\frac{1}{2}$ a pound of powder to every ton of rock. *l l r* means the line of least resistance.

57. Clay is the best material for **tamping.** The line of least resistance should be horizontal, and not more than $\frac{2}{3}$ of the height of rock to be loosened; the weight of rock loosened : weight of powder used, as 10,000 : 1; if the powder is judiciously used.

58. One pound of powder = 30 cub. inches; therefore if the hole be 1″ diameter, 1 lb. of powder will occupy 38·2 linear inches of its depth.

59. Dams are to exclude water; if from a foundation, the materials may be timber, iron, and clay puddle. Hydraulic concrete is sometimes used.

60. A clay dam is sufficient, provided a bed be dug for it, in firm ground and still water, up to 3′ or 4′ deep. The clay is **pressed in layers,** and the water subsequently pumped out.

61. Above 4′ deep, or wherever there is a current, a **coffer-dam** is necessary. It consists mainly of two parallel rows of **sheet piling**, enclosing between them a vertical wall of **clay puddle.** The upper **wales** of the two walls of sheet piling are tied together by cross beams, which support a stage for the workmen.

62. The **guide piles** in one row are about 5′ apart, and the two rows 6′ apart. When these are firm the

sheet piling is driven and firmly wedged between; then the intermediate space is excavated, and **clay puddle** rammed (No. 54) in layers of 12″ thick between the rows of sheet piling.

63. The ordinary rule for **thickness of a coffer-dam** is to make it equal to the height above ground up to a height of 10′; above 10 feet make the surplus **thickness** above 10′ = $\frac{1}{3}$ of the surplus **height** above 10′.

64. When the height exceeds 15′, more **rows of sheet piling** may be driven, always 6′ apart, but the height of the rows may diminish inwards, as it were in steps, the outermost being the full height.

65. From 2′ to 5′ would be sufficient to make a clay puddle dam **water-tight**, but the extra thickness is wanted for **stability**, bracing being inadmissible from row to row, lest the struts should conduct water streams through the puddle.

66. Thin dams are admissible if braced by struts **from within**. The struts are raking, and their upper ends abut against the main or guide piles of the inner face of the dam, their lower ends against **footblocks** in hard ground, or piles driven for the purpose in soft ground.

67. When a **coffer-dam** is exposed to **waves**, the strength of the dam must be adapted to a pressure due to double the depth of still water. Thus pressure against a given vertical surface in still water = area in feet × depth of centre of gravity × 62·4 lbs. for fresh water (or 64 lbs. for sea water). Call this pressure P, then P × height of centre of pressure = t cos. θ × h, where t is the thrust of the strut, θ the angle of its inclination to the horizon, and $h = l$ sin. θ, the height of the upper end of the strut.

68. Planks laid **horizontally on edge** may be substituted for sheet piling. They are laid between a

double row of guide piles. The **planks** must not be less than $2\frac{1}{2}''$ thick, and if the guide piles be $5'$ apart in their row this strength will be sufficient to a depth of $6'$; above $6'$ deep the thickness of plank varies as the root of the depth.

69. On **rock**, vertical iron rods may be **jumped** $1'\ 3''$ into the rock, three feet apart in two parallel rows; on the adjacent sides of the two rows are laid horizontal planks on edge. Clay puddle is rammed between them, the rods acting as **guide piles.** Outside the rods are parallel horizontal timber **wales**, bolted through at vertical intervals of $5'$ or so. These are always fixed in pairs, bolted right through the dam's thickness. The whole is strengthened by inclined timber struts inside. (No. 67.)

70. Where there are **waves**, a number of **caissons** may be floated out, moored in line, and sunk gradually till they begin to touch the bottom. Two rows of main piles are then lowered vertically, one on each side of the caissons, till they, too, just touch the bottom, and are firmly bolted to the sides of the caissons, which are now loaded. Next drive a **third** row of piles or posts inside of the caisson-bolted row; place linings of horizontal planks on edge to line these two inner rows of piles, and ram clay puddle between the plank linings as above. (No. 68.) When the foundation is finished the caissons may be unloaded and floated away, piles and all.

71. Caissons used thus are not suitable for water-tight dams, but only for protection from **waves.**

72. Crib-work dams, where timber is abundant and cheap, are formed of series of layers of logs, laid alternately lengthways and crossways, notched, and pinned to each other at their intersections. This forms a skeleton frame, which is floated out and sunk by stones laid upon

platforms supported by the layers of logs. The structure can then be used as a **caisson** dam. (No. 70.)

73. Sub-aqueous excavation is performed by dredging, or blasting, or diving, without excluding the water.

74. Dredging may be done with a "spoon and bag," that is, a pole with a canvas bag at the end, provided with a sharp **steeled edged** iron ring round its mouth. The pole and scoop are worked by hand, and the labour up to 5′ deep and cost are not much greater than for excavating on dry land; but above 10′ deep this mode is not applicable.

75. The **dredging machine** consists essentially of a pair of parallel chains carrying a series of **buckets** for soft ground, or of buckets and rakes alternately for hard ground. The chains are driven by **pullies.** The machine may be fixed in a **well** in the middle of the stern of a strong barge, over the stern of which the buckets empty into a mud boat.

76. A **steam dredge** of 16 h. p. at best will raise 140 tons = 100 cubic yards per hour, at 4*d.* to 8*d.* per yard. The larger the steam dredge the less the cost of working will be in proportion.

77. The **diving bell** must be used to prepare blasts in deep water, or to lift large stones, which is effected by means of a **lewis** (No. X., 61) attached to a boat.

78. Regular **masonry** requires **diving** apparatus during the **whole** of its construction.

79. Stone and **gravel** may be tipped from a stage into water. The diameter of the pieces in feet should not be less than $\frac{1}{24}$ × velocity of the current in feet per second.

80. If the exterior of an **embankment** be of **stones,** the interior may be of smaller and softer material.

81. In still water an **embankment** will stand with a slope of from 1 to 1 to 2 to 1.

82. Where there are **waves** an **embankment** must be faced with blocks of stone **hand-set.**

83. A loose stone **embankment** may be protected by a wooden crib-work. (72.)

84. Where **hydraulic concrete** is used it may be simply poured into the enclosure made for it, and levelled in layers by a diving apparatus.

85. **Sea walls** for **lighthouses, breakwaters,** &c., may be faced with enormous **blocks** of **hydraulic concrete** (No. VI., 15), from 12 cub. yds. to 27 cub. yds. in volume, which are raised by a lewis attached to a jib crane and lowered into position.

86. **Sea walls** may be protected from corrosion by a 3″ coating of **asphaltic concrete.** (No. VI., 21.)

87. The **masonry** of such facing for **sea walls,** if **ashlar,** should be **cramped** with metal cramps, and the stones dovetailed together. The beds may also be **tabled** and **grooved,** that is, cut into projections and hollows fitting vertically into each other.

88. The best material for a **water-tight embankment** is clay, the next best is firm unsplit rock.

89. The top of a **water embankment** should be from 3′ to 10′ above high-water level. It should be **flat,** and as broad as $\frac{1}{3}$ of the greatest height.

90. The **slope** on the water side may be 3 to 1; that on the land side may be much steeper, say $1\frac{1}{2}$ to 1, or 2 to 1.

91. It is a good plan to make **wooden models** in framework for a proposed embankment, and erect one at each end. This obviates the necessity for intermediate measurements in straight portions.

92. The **water slope** should be pitched, that is, faced with dry stone 1′ thick up to a height of 3′ above high-water level. The **land slope** should be faced with sods.

93. The **top** may be either **sodded** or made into a

road, but must have a convexity of 6″ in the middle to run off water.

94. Neither **trees** nor **stakes** are allowable **on** an embankment, but trees are very useful at the foot of the **land slope.**

95. In the **middle** of the embankment is built a **clay-puddle** wall (No. 54), whose base is $\frac{1}{3}$ of its height, and top is $\frac{1}{6}$ of its height, to render the bank impervious.

96. The **burrowing** of rats, &c., may be stopped by mixing engine ashes with the **clay puddle,** but not much must be used, or the admixture would render the wall pervious.

97. The **joints** must be made quite **water-tight,** both where the clay puddle touches the ground, or where it joins the clay-puddle coating of the culverts.

98. During the construction of a **water embankment** a **by-wash** should be provided to carry off rain.

99. The ground is **prepared** for an embankment to hold water by stripping off the soil and excavating all porous material, such as sand, gravel, or fissured rock, and roots.

100. A **by-wash** is described in No. IV., 69.

101. Retaining walls may be built at the foot of **embankment slopes;** they **must** be in hydraulic morter.

102. Where the **gorge is low** or narrow, or both, a **wall** whose thickness at base is $\frac{3}{5}$ of its height, and at top $\frac{3}{20}$ of its height, may be substituted for an embankment. Its section may be an isosceles triangle, and the morter **must** be hydraulic.

103. The chief object of water-channel engineering is to protect the **banks.**

104. **Banks** may be **protected** by a thick growth of water plants, say willows, if impeding the velocity of the current be no objection.

105. Artificial protection consists of:—1, fascines; 2, timber sheeting; 3, iron sheeting; 4, crib-work; 5, stone pitching; 6, retaining walls; 7, groins.

106. Fascines may be 12′ long, 9″ diameter, tied every 4″ of their length. They may be laid **below** the low-water level by picketing their upper ends with 4′ stakes, and loading the lower ends with stones. **Above** low-water level the fascines are laid horizontally in layers, forming steps corresponding to the slope of the embankment with their **butt ends**, which are turned towards the stream. Each layer is picketed with three rows of 4′ stakes.

107. The heads of the **pickets** should project 8″, and have wickerwork wattled round them, to form a bed for a layer of gravel.

108. Fascines will last for about six years **above** low-water level, and ten years **under** it.

109. Timber sheeting may consist of either sheet piling, or of **guide piles** at intervals in pairs, with horizontal planking on edge between them.

110. The **wales** of the guide piles must be anchored back to buried planks in the bank.

111. Iron sheeting must also be anchored back into the bank.

112. Crib-work, where timber is plentiful, consists of logs notched on to each other in layers at right angles; that is, alternate layers lengthways and crossways. The interval between two adjacent logs in the same layer is equal to 4 × diameter of either log. The intervals are rammed with clay **and** gravel.

113. Dry stone pitching may be used for slopes flatter than 1 to 1. The stones are roughly squared, and laid by hand in courses increasing from 12″ thick at top, to the bottom at the rate of 1″ per foot of height.

114. The **foot** of the **pitching** must abut against a

foundation, to keep it from slipping. This foundation may consist of **oblong baskets**, each holding 2 cubic yards of gravel; or it may consist of a row of **piles** with horizontal wales at the near-shore side of their heads.

115. Retaining walls are chiefly used where **quays** are required.

116. Groins are small dykes projecting at right angles to the bank to obstruct the current. Each groin protects a portion of bank below it equal to five times its own length, and above it equal to three times its length. It may be made of loose stones, piles and planks, or of wattled stakes. Groins should never be permanent, as they do much injury to the channel in ordinary rivers.

117. Regulating dykes should be very cautiously adopted when the width is **beyond doubt** excessive; even then they should not be too high, lest they contract flood waters. They may be built of **dry stone**, slope 1 to 1, or of **wattled piles** and gravel.

118. To construct a **dyke** of **wattled piles**, the diameter of the piles is to be $\frac{1}{20}$ of their length; they are driven in two parallel rows to a depth equal to 2 × depth of water, at a distance apart longitudinally along the row equal to the depth of water, and with a distance transversely between the rows equal to $1\frac{1}{2}$ × depth of water. These rows of piles are now firmly fastened transversely, and wattled longitudinally with willow twigs. The space between the two rows is filled with gravel.

119. A **weir** is an embankment or **dam** made of stone or timber, to bank up the water above it.

120. In building a **weir**, the **line, position, form** of **cross section**, and **construction proper**, are the points to be considered.

121. The best **line**, or form of plan for a weir, is that of Λ, a letter V with the angle up-stream. The best

position is at the bottom of a long straight reach of the river. The Λ should be higher at the sides than in the middle, as this diverts the cascade from the banks below it, as also does the Λ shape of the plan.

122. The up-stream **side** of a **weir** may be **vertical,** to a slope of 1 to 1; the **top,** level and 3′ wide. The **down-stream side** may slope from 3 to 1 to 5 to 1, or may be nearly vertical if protected by a pitching of timber or stone in the form of an apron below it; to prevent undermining, the best form is to cut the lower side into **steps,** on a slope of 3 to 1. The side may be vertical, with a ridge below it damming the fallen water into a **well** to break its own fall from above.

123. The bank extremities of a **weir** are called its **roots,** and should be well bedded to prevent **turning** or **undermining.**

124. A **weir** may be constructed of **timber,** or of timber, stones, and clay combined. In this case the back, crest, and front must be protected by planking laid parallel to the current, and the bottom of the channel, at the foot of the weir, must have a platform of planks on a timber grating or on piles, or there must be stone pitching to prevent undermining.

125. A **weir** may be made of **fascines** in horizontal layers picketed down, with mixed clay and gravel packed between them, heed being always given to protect the front crest and back by fascines laid longitudinally.

126. A **dry stone weir** may be made with a steep slope at back and a long slope in front faced with square stones set in courses. Piles and horizontal wales, both longitudinal and transverse, may be added, to give stability to a dry stone weir.

127. A **solid masonry weir** may be built on an excavation, on a bed of concrete, on a timber platform, or on piles, as deemed expedient.

128. When a **timber platform** is used, a row of sheet piles will be necessary, to prevent **under scour at** the up-stream side.

129. No **down-stream timbers** should traverse a dam or weir, as they tend to conduct water through.

130. The **masonry in all such works** should be in **cement**, or in quickly setting hydraulic morter. (No. 102.)

131. The **heart of a weir** may be of coursed rubble, or of layers of concrete; the **facing** should be of good block in course, or hammer-dressed ashlar; the **crest** should form a coping of large stones, all headers, dowelled together.

132. Besides being well bedded into the banks, the **roots of a weir** may **abut** upon side walls running up and down stream, and backed by counterforts to intercept filtration.

133. A **weir** always requires **waste sluices**, or flood gates. A **sluice** is a **sliding valve** of timber or iron, moving in vertical guides or grooves inside a rectangular passage of timber or masonry. It is generally worked by a screw, or a rack and pinion.

134. A **sluice** should never be **wider** than 5′.

135. **Needles** are vertical bars of wood, which can be slid up one by one to open a channel. They must be strong enough to stand the pressure of the water on their upper sides. They rest against **two sills** across the opening, one at the top and one at the bottom.

136. A **movable weir** is generally a water-tight planked timber gate, or fall door, turning on a horizontal hinge at its bottom, so as to lie flat in a recess in the bottom when open. It must open **down stream**, and may be supported at any degree of opening by struts on the down-stream side.

137. If an embankment have a channel running along

its top, it should be **6′ wide** at the top on **each side** of the channel.

138. All **masonry** in embankments **near water** should be embedded in clay puddle or hydraulic concrete.

139. Drainage embankments should be of clay, rammed in layers, the slopes 2 to 1, pitched with stone on the **current side**, and sodded elsewhere.

140. Canal embankments should be formed and rammed in thin layers, and may be 12′ wide on one side to give room for the **towing path**, and 6′ wide at top on the other side.

141. Each embankment of a canal has a vertical puddle wall 3′ thick down its centre.

142. In **cuttings**, remember to leave a **12′ berm** for the **towing path** on one side, and to make a side drain at the foot of the slope on the berm; on the other side there should be a 4′ berm at the same level, with side drain.

143. The **slopes** should be pitched with dry stone 9″ thick.

144. In some soil it may be necessary to **line** a canal with concrete or sheet piling **at the banks.**

145. Groins run out into the sea, intercept travelling sand, reclaim land, and prevent undermining; an **earthen dyke** will answer, with slopes from 3 to 1 to 12 to 1, top level 6′ above high-water mark, back slope 3 to 1, drained on the land side, with a **wall of fascines** in its heart, the exterior slope faced with fascines, top and back turfed, or, if accessible to crests of storm-waves, pitched with dry stone and sloped at 5 to 1.

146. Stone bulwarks should be either **very** flat or **very** steep: a flat bulwark may have an exterior slope of from 3 to 1 to 7 to 1 near the surface, and 1 to 1 to 3 to 1 below the surface depth. It may be made of

earth and gravel, or loose stones, faced with blocks, each heavy enough to stand alone; the **toe** at the base may be turned up to counteract undermining.

147. A **sea wall** should present an uniform, unbroken face to the waves; it may be topped by a flat **berm** on which a parapet wall is built, set well back from the sea.

148. The **largest blocks** should be **at** and **near** half-tide level, the waves being largest at **half flood.**

149. A **steep-faced** sea wall should be proportioned like a reservoir wall—coped with large stones, cramped or dowelled; no projection on the sea side; face of wall hammer-dressed ashlar, backed by coursed rubble **or** strong concrete; the whole built in strong hydraulic morter, and the outer joints laid in cement.

150. The chief **danger** in a **sea wall** is of stones jumping out.

151. A **sea wall** should be protected from undermining by a disconnected flat stone pitching at its base, and if sandy beach, by groins; moreover, its outer face may be built in **steps.**

152. The **stones** in a **sea wall** should be laid nearly on edge, instead of flat.

153. An **embankment** behind a sea wall should have a retaining wall on the land side; all side **slopes** whatever should have some **protection,** whether of grass, sods, or clay, hurdles, grass ropes, or slabs of stone.

154. A **combined wall** is a steep wall on a long slope. In this case a slope is carried from the bottom up to near low-water mark of 3 to 1, terminating in a long nearly level **berm,** called a **foreshore,** and on that foreshore is built a steep wall at a distance back from the sea edge $= 3 \times$ length of the slope.

155. A **breakwater** is intended to defend a harbour

or roadstead from the waves; it differs therefore from **a bulwark** in having sea on **both** sides.

156. The **site** of a **breakwater** should be such as to break the force of prevalent flood-current storms; it may be detached from the shore, as at Plymouth and Cherbourg, or run out from the up-stream corner of the entrance to the inlet or harbour, as there it opposes flood currents alone.

157. The **back** of a vertical-fronted **breakwater** is usually vertical, always so if used as a quay; otherwise the back has simply a steeper slope than the sea side.

158. When a **stage on screw piles** is used to tip the materials from, the piles remain **embedded** in the breakwater; they may consist of many baulks of timber hooped together, if in deep water.

159. Quays are a class of retaining walls; their ordinary thickness at base = $\frac{1}{3}$ to $\frac{1}{2}$ their height.

160. The face of a **stone quay** may be protected by fender piles connected by **fender wales.**

161. When a river requires a **main embankment,** its tributaries generally will require **branch** embankments.

162. Land-arms are **branch** embankments diverging across the land from the main embankment to save a portion from floods in the event of breaches occurring in the main embankment.

163. A **back-drain** is dug behind the river embankment, and discharges into the river. (IV., 116.)

164. The face of a bank has frequently to be supported by a **retaining wall,** whose stability of **position** is ascertained by taking moments about the **heel** or turning point of the block under pressure; the stability of **friction** is ensured by keeping the inclination of the courses below φ, the angle of repose (No. 3) of the

material: these two conditions ought to be fulfilled at the bed joint of each course.

165. There should be no **tension** at any part of a bed.

166. The **stability** of a **retaining wall**, backed by counterforts well bonded, is equal to that of an uniform wall of calculated **intermediate** thickness.

167. A **surcharged retaining wall** supports a bank of earth above it at its natural slope φ, besides the mass behind it; the pressure is intermediate between that of the back mass alone, and that of the back mass + that of the superincumbent slope indefinitely prolonged.

168. Along the **base of the front** of a **retaining wall** there should run a surface drain: the wall should be provided with **weeping holes** 3″ wide × depth of a course in height, one to every 4 square yards of face. The back should be built in steps; the **thickness at base** may be $\frac{1}{4}$ of height, at top $\frac{1}{8}$ of height; the steps at the back, or **scarcements**, as they are called, may diminish as they ascend, 6″ in every 4′ or 5′ of height; the face may have a **batter** of 1 in 12, **straight batter**; **curved batter** being tedious, difficult, and hard to test by cumbrous moulds.

169. If the **soil be retentive** of water, as clay, a vertical layer of stones or coarse gravel 12″ thick should back it to let water percolate freely; if the soil be **sand** or **gravel**, this is unnecessary, and the **retaining wall** may support it immediately.

170. **Land-ties** are iron rods connecting a **retaining wall**, with plates of iron embedded in a firm stratum behind, when the retaining wall itself is in bad soil.

171. Large **retaining walls** may be of coursed rubble, concrete, or beton, **backed** with block in course, and faced with ashlar or block in course.

172. The **base** of a retaining wall may be kept back

by **struts** of masonry or brickwork; if on both sides of a cutting, by an inverted arch. The upper parts of such retaining walls may be kept back also by slightly arched ribs of cast iron or brick.

173. **Relieving arches** may be made behind a **retaining wall**, so as to save material and pressure. These may be constructed in tiers.

174. **Straight batter** should always be preferred to curved batter, both on account of the facility of construction and measurement, as well as to avoid the cumbrous face moulds necessary in testing the accuracy of face walls when curved in vertical section.

175. **Land slips** are chiefly owing to defective **drainage.** For cuttings; side drains (No. 26), or central drains, if there is deficiency of width, may be used. The barrel drains, made either of brick on edge or of semicylindrical tiles, are suitable for these.

176. When an **embankment** is more than 15′ high, it is well to construct it in two parallel portions, leaving a depression or valley between the two ridges.

177. In **equalizing earthwork** (No. 17), the rammed earth, or "**made ground,**" as it is called, occupies **less** space than before excavation, unless it be rock: the proportion is about as 10 : 9. When first thrown out, the proportion is the other way, *viz.* deblai : remblai :: 10 : 11.

178. All **earthen embankments**, however carefully made and punned, are insufficient without **a clay-puddle wall** (No. 95) for the retention of **water.** For such a wall a soft loamy clay is best. The silt of tidal rivers is also excellent for the purpose. The cheapest way is to build the wall simultaneously with the bank; but for an existing bank which is found to leak, a **puddle gutter** 3′ wide may be dug down the middle of the bank 1′ 6″ into the ground below the bank, and

the clay puddle thrown in and trodden in layers 9″ deep.

179. A layer 3′ deep of **clay puddle** may be laid under the entire **bottom** of the reservoir or navigable canal to retain the water in otherwise permeable soil. In this case the puddle walls and bottom are connected by being worked together on the natural soil, the walls being raised as soon as the clay is hard enough to bear the material for the interior slopes of the banks, which have to be artificially made and added on the inner side of the puddle wall.

180. Dry stone walling is largely used to retain earth behind and above it. Such a wall is specially apt to fail by bulging out at its middle height. To obviate this, it should lie well back and have a batter of 1 to 4 of height.

181. Where embankments are to **protect** land from river **inundation**, the **ends** must rest on high ground at some distance inland from the cutting away of the current; the earth not to be dug up within 20′ of toe of either slope. **Sand** may be used for the **heart**, but not for the slopes. Light **clay** is not so fissile as stiff clay, and therefore preferable. A top width of 8′, rear or land slope of 1½ to 1, and water slope not less than 5 to 1.

182. If the **foundation** of an embankment be bog, it should be drained, or the subsoil consolidated by wooden piles or stakes driven 5′ down; or the surface may be excavated 3′ deep and filled with sand, or both methods combined. **Sand piles** are made by driving wooden piles 12″ diameter, withdrawing them, and filling in the hole with sand well rammed home. This is repeated at 3′ intervals in the clear in each direction all over the surface of the bog.

183. Dry streams crossed by a **band** or **embankment** must be filled up well in front, else the flood

waters will speedily cut through the bank. Piles and brushwood spurs may be combined to avert streams from cutting an embankment.

184. The **width** of a **coffer-dam** between the sheet piling should be regulated to serve as a **scaffolding** for the machinery and materials at work, as well as to be impermeable to water. The enclosed space should be large enough to receive the bed of the foundations, as well as materials and machinery, if wanted.

185. The upper **wales** may be 1′ 6″ above the highest water-line, notched and bolted on to each guide pile or gauge pile, which are, for a slight dam with a single row of sheeting, say 4′ 6″ apart in the clear; forming bays, within which the sheet piles are driven and wedged together. The **exterior** of the single row of sheet piling is excavated and rammed with **clay puddle** or clay **and** sand well poached together.

186. The **gauge piles** of a **coffer-dam** may be rung with iron hoops 3″ × $\frac{1}{2}$ an inch, and shod with cast-iron shoes having square shoulders for the piles to rest on.

187. The **sheeting piles** need not be shod, but should have their ends cut to an inclined edge to give each a drift towards its neighbour. The sheeting piles will be carefully fitted together on the ground before they are driven.

188. The **wedge piles** may be **tapered** 2″ in the lower 6′, the sides above 6′ being continued parallel.

189. A **space,** 43′ × 10′ in the clear, was thus enclosed within a **single row** of sheet piling; the **gauge piles** being 9″ square, driven 17′ below the water line, and standing out 5′ 6″ above it; the **sheet piles** all 9″ × 4″, and driven 15′ below the water line, with their heads 1′ 3″ above it.

190. In order to **drive** the **sheet** piling, as soon as the gauge piles were driven home, two rows of tempo-

rary double waling were bolted on, each wale 6″ × 4″, and 4′ clear interval vertically between the rows, fastened by $\frac{3}{4}$-inch iron bolts and nuts to the gauge piles, against which they are also notched sideways.

191. Each **gauge pile was braced** (when the sheeting was done) both by a **shore** of timber 6″ × 6″ bridging over to the opposite gauge pile, and with a flat bar-iron tie, $2\frac{1}{2}''$ × $\frac{3}{8}''$, connecting its head by slots and wedge keys bearing against iron-plate washers, to the head of a 6″ × 6″ pile, driven 10′ into the ground at a distance of 8′ behind it, with its head 1′ 6″ out of the ground.

192. The **excavation** was then commenced both inside and outside of the dam; the outside was laid and **pressed** (not rammed) with **clay puddle**, disturbing the water as little as possible; the inside was caulked, and payed over with oakum and tar.

193. The concrete for the foundation was lowered **through** the water in baskets, and upset on reaching the bottom, till the layer was 12″ thick. Twenty days were allowed for it to **set**, then the water was pumped out, and the foundation laid of stone masonry in cement, clay puddle being rammed well round it to fill the interval between the pier and the sheet piling.

194. The **coffer-dam** was **left complete** in its place when the pier was finished, the gauge and other piles being cut off 6″ below low-water line.

195. When the **water** is **deep, a caisson** may form a cheaper dam than a coffer-dam.

196. The following being the **angles of repose** for various soils :—

Fine dry sand ϕ	= 35° 30′
,, gravel ϕ	= 39°
Loose shingle, dry ϕ	= 39°
Common earth, dry ϕ	= 46° 30′
,, ,, damp ϕ	= 54°
,, ,, most compact ϕ	= 55°

197. The **thickness** proper for the **base** of a triangular sectioned retaining wall, in terms of its vertical height, would be:—

Vegetable mould carefully laid in courses	·185
Clay well rammed	·195
Earth mixed with large gravel	·250
Sand	·250
Sand or mud in a fluid state	·700
Water	·500

Specific gravity of the wall being assumed equal to that of earth, or 135 lbs. per cubic foot. The minimum thickness at top is 1′ 6″ (or $\frac{1}{10}$th of H up to 30′ high); the maximum thickness, 3′ at top.

198. The contractor should be bound to **dress** the **slopes** of his **embankments** as the work progresses; the slopes to be covered with turf 8″ thick, this again with soil 6″ thick. Equal parts of lucerne and trefoil to be sown in the proportion of 3 lbs. mixed seed to an acre of slope.

199. No **particles** larger than **6″ diameter** are to be used in the embankment.

200. Embankments sink for **years** after construction. On railways, the common allowance is 1″ per 1′.

201. As a **fixed rule,** embankments should never have a steeper **slope** than $1\frac{1}{2}$ **to** 1, or 1 **in** $1\frac{1}{2}$; they require slopes of **one-half longer** base than equally high **cuttings** would require.

202. Rock will stand vertically, or overhanging a **cutting** if firm. Stratified rock, if no seams of clay intervene, requires $\frac{1}{4}$ to 1.

Indurated gravel, 20′ high	1 to 1
„ „ above 20′ high ..	$1\frac{1}{4}$ or $1\frac{1}{2}$ to 1
Pure clay up to 20′ high	$1\frac{1}{2}$ to 1
Clay mixed with sand or gravel ..	3 to 1

203. In forming an **embankment**, the base must be made the **full width** from the first, and while the earth

is being rammed in **layers** the sides are kept higher than the middle; this is best ensured by **double tipping.**

204. A form of **wheel-barrow** with the **centre of gravity** better placed, namely, close below the axle of the wheel, would greatly increase the efficiency and ease of working in earth.

205. The **drainage** must proceed **at the same time** as the earthwork itself, not be left till its completion.

206. **Average drains** may be 3′ wide at top, 9″ wide at bottom, and 2′ deep, to 5′ wide at top, 1′ 6″ wide at bottom, and 3′ deep.

207. When a **road** runs over **marshy soil**, the **side drains** should be made deep enough to furnish deblai for raising the bed of the road on a **bank** 3′ high throughout above the natural surface of the ground. This is called **side cutting.**

208. In constructing a **culvert**, the first point is to take the levels, determine the route, dig and level the bed. The sides are propped by posts or poles, and boarding if necessary. Where a road has to be passed under, only half the width of the road is taken up at a time; when the culvert is finished so far, the road is relaid and the other half taken up. A 3′ diameter egg-shaped **sewer** may have its upper arch of two half-brick rings, lower arch or invert of two half-brick rings, and its sides of one brick thick.

209. Wherever **excavation** or earthwork is carried on near public thoroughfares, the ground must be **protected** by **fencing** off, and at night lamps must be **kept** burning, else an action for damages may be the result of any accident. Where actual **building** is going on, it is convenient to surround the site with **boarding** before commencing operations.

210. A rough **coffer-dam** may be made by driving

two rows of piles as guides; against the inner sides of these mere **boards** are laid on edge one above another, close jointed, and clay is rammed between. A steam engine (small horizontal portable engine) is cheaply employed for pumping out the water which leaks in through such a dam. The lower boards may be nailed previously on to sharp-pointed stakes, which are laid at suitable intervals to fall between the guide piles, and then placed upright in position, and the whole frame driven down together. The guides may be 9″ to 1′ diameter × 20′ long at 3′ or 4′ intervals.

211. For **retaining** and **breast** walls, calculations are very little use, owing to the variable nature of the local conditions and material used. A **batter** of $\frac{1}{10}$th to $\frac{1}{8}$th of the height is ample; $\frac{1}{12}$th is usual in fine cut work; $\frac{1}{5}$th of the height **has** been given, but moss begins to grow if the slope is so flat; $\frac{1}{4}$ is used for dry stone walls.

212. Counterforts should be as **thick** as the wall; their breadth $= \frac{3}{2} \times$ thickness, and their intervals apart = three times their thickness.

213. The **wall** should be **thick** enough to resist the pressure of the earth **without** the aid of the counterforts. The thickness is always given in terms of the height, between the limits, however, of 1′ 6″ as a minimum and 3′ as a maximum surface thickness at top.

214. The following **formulæ** are deduced from experiment, and are believed to be the best known :—

let h = the height of the wall in feet,
t = its mean thickness,
w = the weight of a cubic foot of its material;
then $h\,t\,w$ = the weight of a **running foot** of the wall,
s = weight of a cubic foot of the earth retained.
$c = \cot. \dfrac{\varphi}{2}$,
$n = \frac{1}{2}$ for rectangular walls.

For earth $t = h c \sqrt{\frac{s}{5 w n}}$.

For water $t = h \sqrt{\frac{62 \cdot 5}{5 w n}}$,

g = the force of gravity = $32 \cdot 2$ approximately.
$62 \cdot 5$ lbs. = the weight of a cubic foot of water.

215. For a rectangular stone wall, $n = \frac{1}{2}$, $w = 130$ lbs., $t = \cdot 3\, h$. For a wall **with a batter** of $\frac{1}{6}$th, $n = \cdot 6043$, $t = \cdot 27\, h$. For a rectangular stone wall to resist water pressure,

$$t = h \sqrt{\frac{62 \cdot 5}{5 w n}} = h \sqrt{\frac{12 \cdot 5}{w n}}, \qquad n = \tfrac{1}{2},$$
$$t = \cdot 44\, h.$$

If such a wall has a **batter** of $\frac{1}{6} h$, $t = \cdot 4\, h$.

216. The **centre of gravity** of a triangle being at a distance of $\frac{1}{3}$rd the height from the middle of the base, it follows that the tendency to **bulge out**, observable in badly built **retaining walls**, will be most powerfully exerted at a point behind the wall $\frac{1}{3}$rd of the wall's height measured from its top downwards. The **exact** centre of pressure will depend upon the nature of the soil, its angle of repose ϕ, and condition wet or dry; all which considerations affect the angle of repose ϕ, of the retained mass, and consequently also the size and shape of the vertical section of the triangular prism **actually supported** by the wall. The actual thrust may be considered to act from the centre of gravity of the earthen prism in a direction parallel to the natural slope of the material, so as to cut the back of the retaining wall at **one-third its height** from its **bottom.**

216a. Another rule (212) for **counterforts** is that the thickness of counterfort = $\frac{1}{2}$ thickness of wall; breadth of counterfort = thickness of the wall; interval apart in the clear = 2 × thickness of wall.

217. Timber and iron **bond** are introduced to bind the **counterfort** to the main wall.

218. In **filling** earth behind **retaining walls,** lay it in thin layers 1′ thick, **sloping away** from the wall, and punn it cautiously to 6′ distance measured back from the wall. Beyond that distance it may be tipped and consolidated in the usual way.

219. In **excavating** for breast walls and turning toes of slopes, **no more** should be excavated than is **necessary,** because all that is filled in again will have to be retained by walling.

220. No stone containing **lime in it** should be allowed in works on the sea. The insect (*saxicava rodosa*) eats lime, but does not touch silex.

221. Table of thicknesses of **retaining walls**:—

Batter.	Thickness of Wall at Top in feet and decimals.					
Vertical	Height ×	·336	for clay, or	Height ×	·267	for sand.
1 in 12	"	·256	"	"	·189	"
1 " 8	"	·218	"	"	·153	"
1 " 6	"	·183	"	"	·118	"
1 " 5	"	·155	"	"	·092	"
1 " 4	"	·115	"	"	·054	"

CHAPTER IV.

Canals, Channels, Conduits, and Culverts.

Pipes, Water Supply, Reservoirs, and Hydraulics generally.

1. In **draining** always begin at the lower end and work from the **outfall** up hill to the summit.

2. **Catchwater drains** may be **open ditches** 4′ wide and 2′ or 3′ deep, or made of stone, or brick, or earthenware tubes, covered in with loose stone or gravel.

3. In Hydraulics it is usual to **measure** pressure by feet of water: this is called "**Head of water.**"

4. Fresh water **weighs** 62·4 lbs. to the cubic foot, sea water weighs 64 lbs. to the cu. ft.; and there are 277·274 cu. inches to the gallon.

5. **Head** of Fresh water is to head of Sea water as 1·000 is to 1·026.

6. The **absolute Head** of a particle of water under pressure consists of head due to pressure and head due to elevation.

7. When the **absolute pressure** falls short of the atmospheric pressure, the difference is denominated so many feet of **vacuum.**

8. **One gallon** may be assumed equal to 0·16 cub. ft. $=10$ lbs. of water: and a cubic foot of water weighs 1000 ounces $=\frac{100}{16}$ gallons $=6\cdot25$ gallons.

9. The **discharge** of water is measured in cubic feet per second.

10. The **mean velocity** is ascertained by dividing the discharge by the cross section.

11. In a straight reach the **maximum velocity** is at the middle of the surface (cæteris paribus), and the minimum velocity at the bottom of the side.

12. In an ordinary current it is found that

Greatest velocity	:	mean velocity	:	least velocity
:: 5	:	4	:	3

or in very slow streams as 4 : 3 : 2.

13. If (μ) the coefficient of friction, be disregarded, the **loss of head** is equal to the vertical height due to the velocity generated if the particle had fallen freely.

14. Hydraulic **formulæ** are very unsatisfactory; they rest for the most part on mere experiment, and the results differ widely.

15. In an **open channel** the **loss of head** is the actual fall of the surface of the water.

16. In a **close pipe** the loss of head or **virtual fall** may consist wholly or partly of diminution of the head of pressure.

17. The pressure of **flowing water**, as diminished by loss of head, is called **hydraulic pressure.**

18. The pressure of **still water** is denominated **hydrostatic** pressure.

19. If the water **had** a velocity at the starting point assumed, such a velocity is called the **velocity of approach,** and the **difference** will form the basis of the calculation.

20. The **hydraulic mean depth** is the quotient of the vertical section of the fluid, divided by the **border** in contact with the channel.

21. The **hydraulic mean depth** of a cylindrical or square pipe running **full**, or of a semi-cylindrical open conduit, is $\frac{1}{4} \times$ diameter.

22. The **effective** area of a small orifice is less than the absolute area, in a ratio expressed by the **coefficient of contraction.**

23. Such an effective area is called the **vena contracta.**

24. In sharp-edged orifices the **friction** is inappreciable ; in tubes it is all-important.

25. Drowned orifices are such as are entirely submerged.

26. The **velocity** generated is regulated by the **pressure.**

27. The **pressure** on any submerged surface is equal to the weight of a column of water whose horizontal sectional area is equal to the area of the submerged surface in question, and whose height is equal to the depth of the **centre of gravity** of the submerged surface below the surface of the water.

28. The centre of **buoyancy** coincides with the centre of **gravity** of an immersed body; but the centre of **pressure only** does so when the submerged surface is horizontal. In all other cases it is below the centre of gravity, because the pressure at **each** point, constituting the **distribution** of pressure, varies according to the depth of its immersion.

29. The total pressure on an immersed body = $w \,.\, \sin.\, \theta \,.\, \int x\, y\, d\, x$. If the area be wholly submerged x must be taken as a definite integral between the limits giving the **slant depths** of the upper and lower extremities of the submerged surface. θ is the angle of inclination of the plane to the horizon.

30. To determine the **dimensions** of an uniform channel to discharge Q cubic feet per second, with an inclination of $i = \frac{h}{l} = \frac{\text{actual fall}}{\text{length of channel}}$.

First the **figure** or form of section must be assumed; then call A the area of the section; m, the hydraulic mean depth; $\frac{A}{m^2} = n$, a constant whose value is given below.

Now say $m' = \left\{\frac{Q^2}{8512\, n^2\, i}\right\}^{\frac{1}{5}}$ for a first approximation to m.

Also $v' = \frac{Q}{(m')^2\, n}$ for a first approximation to v, the velocity.

Also $i' = \frac{v^2}{64 \cdot 4\, m} \times \left(0 \cdot 00741 \times \frac{0 \cdot 000227}{v}\right)$ for an approximation to i.

If i', as computed thus, agrees very nearly with i, then the value of m' is near enough to m; if not, correct m' thus: $m = m' \left\{\frac{4}{5} + \frac{i'}{5\, i}\right\}$.

31. The values of the constant quantity n, are for—

A semicircle	$n = 6 \cdot 2832.$
Half square	$n = 8 \cdot 00.$
Half hexagon	$n = 4\sqrt{3} = 6 \cdot 928.$
Mr. Neville's section	$n = 4 \text{ cosec. } \theta + 4 \text{ tan. } \frac{\theta}{2}.$

In each of these figures m = half the greatest depth.

32. Whatever the diameter of a pipe is, **one inch** of diameter should be allowed for **incrustation.**

33. Backwater is the effect of damming up water in its course.

34. The time of discharge or of emptying a reservoir may be found thus:—If $d\,t$ be the time of discharge of one layer whose area is s, and thickness $= d\,x$; A, the effective area of the orifice, and c a multiplier taken from hydraulic experiments, then the whole time of emptying $t = \frac{1}{A\, c} \times \int_0^a \frac{s\, d\, x}{\sqrt{x}}$, where x is the height of any layer above the orifice; and the height of top-water level was a.

35. The source of all **water supply** is the rainfall; water which escapes evaporation and absorption runs

into streams or springs or porous strata, and is tapped by **wells.**

36. The primary points to ascertain are the **drainage area** and annual depth of **rainfall.**

37. The **drainage area** is bounded by a **ridge** or **watershed line.** The watershed line may be either a geographical or geological feature, a mountain range, or the side of an impermeable stratum underground.

38. The most important **statistics** are five: 1, the least annual rainfall; 2, the mean annual rainfall; 3, the greatest annual rainfall; 4, the distribution of rainfall throughout the year; 5, the greatest flood rainfall.

39. Rainfall observations are usually recorded to two decimals of an inch. The ratio of

	Least annual	:	**mean**	:	**greatest annual rainfall**
as	**3**	:	**4**	:	**5 very nearly.**

40. The **available rainfall** is that which remains for use when absorption and evaporation have been deducted. This can only be ascertained by experiment.

41. Weir gauges are the best means for ascertaining discharges of streams; they only answer for small streams.

42. A right-angled triangle, with the vertex downwards, is the best form for a **weir notch.**

43. For **drowned orifices** a circle or square is the best form, and any number may be made at the same depth.

44. Currents may be measured by **current meters** of a fan, revolving on an endless screw, which drives self-recording wheelwork; its sensibility is easily ascertained by experiments at known velocities through **still** water.

45. If no better method is attainable, a **floating body** thrown into the middle of a straight reach will do for a measure.

46. The **channel** where the measurement is taken should be **nearly uniform** and free from weeds, for weeds multiply the friction by 10.

47. If the **daily discharges**, as observed at any waterwork throughout the year, be arranged in order of magnitude, and divided into an upper quarter, middle half, and lower quarter, then the middle half shows the ordinary or **average summer** discharge; the upper quarter shows **floods**; and if the **mean** of the middle half be substituted for **each** of the flood discharges, and the mean of the whole list be taken again as thus modified, the result gives the **average** discharge, exclusive of floods.

48. A **store reservoir** is generally intended for retaining surplus rainfall in floods, to be used in times of drought.

49. The **available storage room** of a reservoir is its volume between the **surface** and the **lowest working level.**

50. The space below the **lowest working level** is called the **bottom,** and is meant to serve for the subsidence of sediment, it may be $\frac{1}{6}$ of the greatest depth.

51. The **size** of an intended reservoir would depend on the **amount** and **fluctuation** of the supply; 120 days' supply is the least of any use in Britain, 140 days' supply is, however, nearly always enough.

52. The **storage room** may vary from $\frac{1}{3}$ to $\frac{1}{2}$ of the available annual rainfall.

53. To determine the **site** of a reservoir, the features of the ground, the elevation, and material must be considered. A reservoir must be **high** enough to **distribute** the water when nearly empty, and low enough to allow a sufficient **gathering ground** (35 to 37) above its highest level.

54. The **best site** for a reservoir is where an

embankment across a **narrow gorge** will embank a large basin.

55. **Plans** of **contour** lines are very useful to show an engineer the **available quantity** in a tank from mere inspection of a vertical scale showing the level of the water in it.

56. One **cross section** should show the **existing** lowest outlet, and another should be prepared to show the **intended** outlet.

57. **Springs** under embankments and **porous strata** under reservoirs are alike to be avoided.

58. The best **material** for a reservoir is clay, and the next best is firm, unsplit rock.

59. Land **awash** means less than 3′ above the highest water-level, and which consequently cannot be properly drained.

60. For reservoir **embankments** see (III., 88 to 102). After stripping and preparing the bed for a bank the next operation is—

61. Building the **culverts** for the **outlet pipes** in cement or strong **hydraulic** morter, resting on a base of hydraulic concrete.

62. If there are to be **pipes in a culvert** they must be accessible, and consequently the least dimensions for the culvert will be 4′ 6″ × 3′ 0″.

63. The **outer end** of a **culvert** is open; the upper end is closed by water-tight masonry, through which the lowest or scouring water pipe passes.

64. A **cast-iron pipe** may be laid without any culvert.

65. Every reservoir must have a **waste weir** at the **highest safe** high-water level, and long enough to carry off all the flood water above that level as fast as it flows into the reservoir; the weir channel or waste channel should deliver into the natural water channel again.

66. The **weir** may be of **ashlar**, or of square **hammer-**

dressed masonry; to protect the lower side from overfall water, it may be built in steps. (See III., 122.)

67. Where the water is wanted **clean**, there must be at least two outlet pipes, one tapping the reservoir clear of the sediment, and the other a **scouring** pipe to drain off the whole to the very bottom.

68. The **mouths of pipes** may be protected from entrance of wood, &c., by convex wire gratings.

69. The **by-wash** is a diversion channel, useful when the embankments are in course of construction, useful also to divert **surplus waters** from the reservoir, over a weir in the supply channel.

70. It may be stipulated that **only a portion** of the water in a river is to be stored in a reservoir, in which case the whole of the water may be conducted past the reservoir in a **by-wash** having **weirs** at such a level that only the surplus water above a certain quantity shall run into the reservoir.

71. A **diversion cut** is a permanent by-wash, to **divert** an impure stream.

72. **Feeders** are permanent small channels for **conducting** streams or drainage **into** the reservoir.

73. Retaining walls, banks, slopes, &c., see (III., 101, 102).

74. To **convert** a lake into a reservoir it is only necessary to provide it with a waste weir and outlets.

75. The **plans** of a water channel, whether existing or proposed, should show the boundaries of lands which are liable to be flooded or laid **awash** (No. 59) by it in case of floods. The utility of such plans is greatly increased by **contour** lines.

76. A **longitudinal section** should be prepared, showing the centre line of the channel. Sections should also be made on the line of most rapid current, of each bank, and of the deepest part; **cross sections** should

also be prepared where an existing channel is very variable in dimensions, and these cross sections should be **prolonged** right through **land** which may become flooded or **awash.** There must be accurate drawings of the archways, roadways, and approaches of existing bridges, weirs, &c.

77. The **strata** must be ascertained by sinking pits, **and** by boring, probing the bottom, &c.

78. Regime means a state of **stability** of the materials forming the **bed** of a channel.

Soft clay is washed away by water flowing with a bottom velocity of 0·25 foot per second.

Nature of Bed.	Velocity of Water at Bottom in feet per second.
Soft clay	0·25
Fine sand	0·50
Gravel the size of peas	0·70
Gravel the size of French beans	1·00
Gravel 1″ diameter	2·25
Soft rock or brick	4·50
Rock	6·00

79. The bottom in a **permanently unstable** soil takes the form of **steps** or long **flat ridges.**

80. The **line** of **strongest current** is always more circuitous than the centre line of the channel.

81. The chief object of **water-channel engineering** is to protect the banks. How this is to be done may be seen (III., 104 to 112).

82. The **defects** in a river **channel** which usually require remedying are too narrow or too shallow a channel; too wide a channel, forming shoals; too flat a declivity, too circuitous a route, too sharp turns; branch channels.

83. Short of actually **diverting the course** of a river the following methods may be adopted to remedy defects, *viz.* excavation or damming.

84. Excavation under water may be done by hand dredging, machine dredging, or blasting. (III., 73.)

A **soft bottom** may be excavated by mooring a boat over it, furnished with a **slanting screen** of boards or framed canvas, which directs the current downwards upon it, the bottom of the frame being 4″ above the bottom of the channel; from 30 to 70 cubic yards can be done in a day by this method.

85. Regulating dykes and dams should be very cautiously adopted. (III., 117.)

86. Branch channels should be stopped at their upper ends by an embankment of stones **and** gravel, advancing simultaneously from the sides to the centre, or by **wattled piles** and gravel if the current be more than **gentle**; if the current be **swift**, a raft, boat, caisson, or cribwork dam, loaded with stones, may be floated out, moored, and sunk; the current being thus stopped, the channel will **silt up** of itself.

87. In substituting a **cut** for a circuitous channel caution is necessary, lest the current be rendered **too strong** for the **stability** of the bed (No. 78). The main current is obliged to take a **definite course** in a slightly **curved** channel, hence such a trace is to be preferred to a perfectly straight one.

88. The best position for a **weir** is at the bottom of a long **straight reach** of the river. (See III., 121.)

89. The best **site** for a **bridge** is at right angles to the current in a long, straight, narrow reach with steep sides.

90. For **conduits** the declivity should not give a current **faster than 4′** per second, or less than 1′ per second.

91. Channels for pure water should be built of brick or stone in **cement,** covered, and may be lined with a coating of **cement,** either calcareous or **asphaltic.** (VI., 18, 3.)

92. If a **conduit** is carried along on **an embankment,** the top of the embankment should be 6′ wide on **each** side of the channel, and the masonry of the channel must be embedded in clay puddle or hydraulic concrete. (III., 54; VI., 15, 14, 13.)

93. The **best forms** of transverse **section** for **channels** are as given in (No. 30). For a **sewer,** the best form is **egg-shaped,** with the small end downwards.

94. The best **form** for a **covered conduit** with uniform flow is circular section.

95. Every **covered conduit** or **tunnel** should be buried at least 3′ underground in **Britain,** to avoid the disintegrating effects of frost, and must be provided with **grated shafts** for ventilation.

96. A **conduit** may be made of a cylinder of **sheet iron,** lined with brickwork in cement; its advantages are great strength combined with moderate quantity of material.

97. For **aqueducts** and aqueduct bridges (see I., 118).

98. **Water pipes** may be of earthenware or of iron.

99. Earthenware **pipes** are made from 2″ to 3′ diameter, from 1′ to 3′ long, and of every degree of hardness; they can stand any degree of continuous pressure, but are easily broken by shocks or sharp blows; their great use, therefore, is for small covered **drainage conduits.** The **joints** are of the **spigot and faucet** form, tightened with cement or bituminous mastic. The **thimble** joint may be used, which consists of a ring loosely fitting the adjacent ends of two lengths of the piping which are inserted in it. Two **half thimbles.** or a half thimble and half **faucet** may be used.

100. **Right-angled** junction pieces should never be made use of.

101. Cast-**iron** water **pipes** are made of all sizes, from

2″ diameter to 4′; they should be cast vertically, that is, standing on end, not horizontally (VIII., 28), with the faucet downwards.

102. The **desiderata** in **iron pipes** are uniformity of thickness, freedom from flaws or air bubbles.

103. The **thickness** necessary for an **iron pipe** to sustain a given pressure is found by the formula,

$$\frac{\text{thickness}}{\text{diameter}} = \frac{t}{d} = \frac{p}{12000},$$

where p is pressure in **feet of water**, and the factor of safety $= 6$; or, in other words, the breaking load is six times the working load.

103a. The **thickness** of a cast-iron pipe should never be less than $\frac{3}{8}$ inch; they are usually in **lengths** of 9′, exclusive of faucet.

104. The **faucet** is a socket on the end of each length to receive within it the plain end of the next; the **plain ends** and **faucets** may be turned to fit exactly, and made water-tight with red lead paint; or the joint may be slack, and run up with melted lead; this forms a more yielding joint, though not so quickly made.

105. **Iron pipes** are best preserved by coating them both inside and outside with pitch.

106. The **virtual head** of water in a pipe is the head to which its velocity of discharge, as actually diminished by friction bends, &c., **would** be due without any friction.

107. If any part of the pipe **rise above** the line of **virtual** declivity, air bubbles will collect, owing to a partial vacuum being formed by the diminution of atmospheric pressure at such places.

108. A pipe so **rising** above the line of **virtual declivity** is called a **siphon.**

109. Air locks may be placed at the summits of siphons to collect the **air**, and **scouring cocks** at the lowest points of an undulating line of pipe to collect the **sediment.**

110. A **pipe** may be used as the **bow** of a Catenary arch; in this case the water helps to bear the thrust. The load borne by the pipe in this case = load per foot of span × radius of curvature at crown in feet × sec. θ, (at the spring of the arch) – pressure of water × sectional area of pipe.

111. The **chief statistics** to be attended to in drainage are the features, extent, levels, rainfall, courses, dimensions, and discharge of the channels.

112. The **water level** in the **branch** drains, which are fed by the **field** drains, should be 3′ below ground at all times, else the land is liable to become flooded or **awash.** (No. 59.)

113. The **declivity** of a channel must be such as to run off water as fast as it can run **in.**

114. Defects in drainage are generally remediable by constructing store reservoirs, removing obstructions, rendering the bed **stable** (No. 78), increasing declivity by shifting the **place** of outfall, cutting a straighter channel, enlarging branch drains, turning pools into temporary flood reservoirs, embanking flood lands.

115. In England as much as 1″ of rain has been known to fall in an hour, and 5″ in 24 hours.

116. A **back drain** is dug behind river embankments, and discharges over them by a siphon or through them by pipes, furnished with **flap valves** of vulcanized india-rubber over an iron grating.

117. When a river has a **main** embankment, its tributaries generally will require branch embankments.

118. Tidal drainage is that of land which lies so low that it can only discharge at low water; such land

requires embanking, and can best be drained by a **canal** right through it, into which the **branch drains** discharge.

119. The **high-water level** of such canals will be low enough to give the branch drains sufficient outfall; the **low-water level** will be 1′ above low water at neap tides.

120. The **space between** these two levels is the **reservoir-room**, and must be sufficient to hold all the possible drainage of one tide's duration; thus the **width** of canal is determined, the length and depth being fixed otherwise.

120a. The **length** of a **drainage canal** will depend upon the extent of the ground to be drained; the depth must be sufficient to discharge all its contents in **two hours** at low water.

121. The **mean velocity** of outflow is that due to a declivity of channel whose height is the difference between high and low water level of the canal, length = the canal's length, and hydraulic mean depth = that of the canal when half way between high and low water mark.

122. A **drainage canal** may discharge by large **flood-gates**, or by **siphon pipes**, or again by steam pumps, in which case the cheapest way is to have a large reservoir and keep the engine **always** at work.

123. Every working part of such an **engine** should be in duplicate to provide for repairs.

124. **Sewers** are underground **covered conduits**, and may be 4′ 6″ × 3′ inside.

125. The **velocity** of flow in a **sewer** may be from 1′ to 4′ 6″ per second.

126. To **flush a sewer** is to place a temporary **dam** above an obstacle till a mass of water collects above;

upon **suddenly removing** the dam, a rush of water scours the channel.

127. Chimneys must be provided for **sewers** to allow the escape of **gas**, which is prevented by siphons or traps from returning to houses; and **passages** to admit **fresh air**; subterranean entrances are necessary with trap-doors to admit men for purposes of repair.

128. Pipe drains usually range from 4″ to 18″ diameter, their slope should give a velocity of 4′ 6″ per second; obstructions most easily occur at junctions, which should therefore be **sloping**, not horizontal.

129. Channels for the **distribution** of water should run at the highest levels consistent with a minimum velocity of 1′ per second.

130. To **estimate** the quantity of **water** wanted for a **town** in England in gallons per diem for each individual as given in the population census, including fires, fountains, washing streets, &c., as **extras.**

	Gallons.		
	Least.	Average.	Greatest.
Domestic purposes	7	10	15
Extras	3	3	3
Trades and manufactures	7	7	7
Total usually consumed	17	20	25
Waste, if carefully managed	2	2	2½
Total demand	19	22	27½

131. To prevent **private waste** they should pay for the water by measure (water mètres); it should be enacted as a condition that domestic water fittings shall be executed to the satisfaction of the company's engineer.

132. The **head of pressure** in each **main** should, when the flow is most rapid, be equivalent to an altitude of 20′ above the tops of the adjoining houses, to deliver water in the highest stories.

133. Pipes are more **expensive** than conduits, and should be **steeper** in the proportion perhaps of pipe's virtual declivity : conduit's actual declivity :: 8 : 1.

134. When the **levels** in a town are very **irregular,** the pressure in a **main** may be in one street even, barely sufficient at one end and excessive at the other; this may be rectified by passing the water through **loaded valves** or small orifices.

135. The maximum hourly demand = 3 × the average hourly demand in a day of 24 hours.

136. Springs are of no use **direct,** only to supply **reservoirs.**

137. When a town is supplied **from a river,** pumping engines, **settling reservoirs,** and filtering beds are usually necessary; especially good settling reservoirs.

138. The **indicated horse power** is about 1·25 time the effective horse power. **Reserve** steam power equal to half the working power should be provided.

139. Air vessels and **stand pipes** are contrivances to break the shock caused by the intermittent throw of the pumping engines.

140. Wells are borings sunk into a **water-bearing** stratum; if through an impermeable stratum overlying it, the boring is called an **Artesian well.**

141. The commonest **impurities** in water are salts of lime and iron; such water is good for drinking, **but** for nothing else. Salts of **lime cause hardness** in water, as it is called; hardness may be corrected by adding **lime,** which forms chalk and is deposited.

142. Drainage water about towns is bad and even dangerous, containing semi-decomposed organic matter.

143. Peat moss unfits water for manufacture, but

not in the least for drinking, as is commonly supposed.

144. The **best water** is from mountain streams, where granite, gneiss, and slate prevail.

145. Spring or well water is **harder** than river; river water than drainage.

146. Living plants and **fish improve** the water of a reservoir.

147. A **store reservoir** may do duty as a settling pond also. (No. 148.)

148. The **filtering bed** may be a tank 5′ deep, having a paved bottom simply covered with open jointed tubular drains discharging into a culvert; the drains may be covered with charcoal, 6″ deep; the layer of charcoal is covered with gravel, 2′ deep; over the gravel there may be a layer of sand, 2′ deep. The water percolates at an ever-varying rate; the filter may be taken out and thoroughly cleansed every month, otherwise it can be known when cleansing is necessary by the slow percolation, which should be at a rate of 6″ vertical descent per hour, and is never likely to be more than 12″ per hour; this rate of course determines the dimensions. The great point is to have a large **settling** reservoir **before** filtering.

149. The use of **town reservoirs** is to allow a **uniform** discharge from the **store** reservoirs to supply the daily demand, while the **fluctuation** falls upon the town reservoirs only.

150. Caution is necessary lest the **accumulation** of water in the **town** reservoirs **nightly** should cause inconvenient **head** of water in the **mains.**

151. Town reservoirs may be made of masonry or brickwork lined with cement, or of rectangular cast-iron plates flanged and bolted together. The opposite sides should be connected across the reservoir by tie rods; the **best figure** is cylindrical.

152. The distributing basin should be placed so as to **command** its district; it should in all cases be **roofed,** either by a masonry vault, or brickwork covered with **asphaltic concrete** to exclude rain, with 3′ of soil and a turf layer.

153. If the **water supply** comes a long **distance,** auxiliary store **reservoirs** should be constructed close to the town, to hold one month's supply, in case of **repairs** being necessary to the main works.

154. In large towns the **total length** of distributing **pipes** may be taken at 1 mile per 3000 persons.

155. The ratio of the **diameters** of branch pipes varies as the fifth root of the volume squared.

$$\sim \sqrt[5]{(\text{volume of water})^2}.$$

156. Branch pipes diminish the flow of water in their main, till the main terminates in **a dead end.** The virtual declivity is **proportional** to the **square** of the distance from the dead end. The **head** at any point minus the head at the dead end, varies as the **cube** of the distance from the dead end.

157. All **dead ends** of pipes should have scouring valves; dead ends may be avoided in service pipes by connecting **each end** with a main.

158. The **constant service** system is **far** the best, for purity, comfort, and durability; on the other hand, the **intermittent service** promotes rust, dirt, and effluvia. The constant service system keeps the distributing pipes always full; the other service supplies districts in **succession.**

159. Where the **intermittent service** system prevails, each house requires a daily store **cistern.**

160. Siphon pipes have been made for a tidal drainage canal (No. 118) 16 in number, 3′ 6″ in diameter, iron $1\frac{1}{8}''$ thick; **summits** 20′ above **low**

water of **spring** tides; **lower ends** 1′ 6″ below low water of spring tides, opening by flap valves down stream. When requisite, the air at their summit is exhausted by a ten-horse power steam engine working an air pump whose cylinders are three in number, 15″ diameter, and length of stroke 18″.

161. Canals may be divided into **level canals**, or ditch canals, consisting of one reach or pond, whose best route is a contour line, or as near it as is practicable; **lateral** canals connecting two places in the same valley, and **summit** canals.

162. Single **locks** at intervals are more economical than the same number in a **flight**: the usual **lift** of a **lock** is from 2′ to 12′; say 7′ to 9′ for an average.

163. The **difficulty** with **summit** canals is to get water for the summit reaches, and to cross passes economically.

164. Short **portions** of a canal may be only **wide** enough for one boat; that is, the least width of canal at the bottom may be twice the maximum width of boat. The least depth of water may be one and a half time the greatest draught of boat; area of waterway may be six times the greatest midship section of boat. If of masonry, the bottom must be 2′ wider.

165. The bottom of a canal is **flat**, the sides not steeper than 1½ to 1, unless of masonry.

166. Power is **economized** by hauling heavy loads at low speeds.

167. The **maximum load** for one horse is 105 tons at 2½ miles per hour; such a boat would measure 70′ × 12′, and draw 4′ 6″ of water when loaded.

168. A **horse** can **draw** a boat 70′ long, 7′ broad, 2′ 6″ draught of water, 4 miles per hour.

169. Boats may be **propelled** by screw, warping chain, or endless wire ropes.

170. The limits of **dimensions** for the construction of canals are at present, for a

	Breadth, Bottom.	Top-water Level Breadth.	Depth of Water.
	feet.	feet.	feet.
Small canal	12	24	4
Ordinary canal ..	25	40	5
Large canal	50	110	20

171. For canal **embankments** see (III., 140); for **canal cuttings** (III., 142).

172. The surface of **towing path** may be 2′ above water level, and slopes slightly **from** the water for foot-hold.

173. The **slopes** should be pitched with dry stone 9″ thick.

174. In some soils it may be necessary to **line** a canal with **concrete** or sheet piling at its sides.

175. Cross watercourses are to be carried below the canal by aqueduct bridges, culverts, siphons **inverted**, either of masonry or iron.

176. Every reach of a canal must have **waste weirs** for flood waters; **sluices** by which it may be emptied for repairs, and **stop gates** every two miles or so, that emptying one division may not affect the adjacent ones.

177. The best **site** for **stop gates** is under a bridge or over an aqueduct.

178. Leaks in canals may sometimes be stopped by shaking loose sand, clay, lime, chaff, &c., into the water at the place.

179. For canal bridges see (I., 107).

180. The **clear length** of a **lock** should include the longest boat used + its rudder. The clear **width** is 1′ + the greatest breadth of a boat; and the depth of a

lock is 1′ 6″ + greatest draught of boat + lift of lock + 2′ 0″ say, from water level to edge of coping.

181. The **side walls** and **floor** of a **lock** are recessed to allow the tail gates to open; the **floor** of a lock is level with the bottom of the **lower** of the two reaches it connects.

182. Lock gates always open **up stream**, consequently the side walls and floor at the **head bay** are continued and recessed above the **head gate.**

183. The **side walls** of a **lock** end into curved wings, the **floor** into a dry stone pitching or **apron.**

184. The **walls** throughout are reinforced by **counterforts** at intervals.

185. The **lower edges** of the lock gates when shut press against the head and tail **mitre sills** Λ shape.

186. Locks are **filled** or **emptied** through **side sluices** or pipes before the gates are opened.

187. The **heel posts** accurately turn in cylindrical recesses cut in the masonry, and called **hollow quoins.**

188. The quoins, hollow quoins, coping, gate chambers, and mitre sills should be of **ashlar masonry.**

189. The **ashlar masonry** of which the **mitre sills** are constructed may be faced with **wood** to stand shocks and form a **tighter joint.** (No. 185, 188.)

190. The heel post turns on a slightly eccentric pivot at **base** to save friction, and at **top** in a circular iron collar.

191. A **canal gate** is **double**; each half consists of a heel post, a mitre post, cross pieces, and cladding; diagonal bracing between the posts may be added; the planking or cladding may run vertically or diagonally, and the lock gate may be constructed either of timber or iron.

192. Gates should have **counterpoise bars** to ease the pivots and act as levers; or **rollers** under the

lowest cróss bars to assist the pivots; each roller runs on a quadrantal iron rail.

193. The following are usual **dimensions** for **locks** and their appurtenances :—

Mitre sills, top 6″ to 9″ above floor level; **Versin** of mitre sill, $\frac{1}{5}$ to $\frac{1}{7}$ of breadth of lock.

Side walls, least thickness at top 4′, greatest thickness at base, $\frac{1}{4}$ to $\frac{1}{2}$ height.

Length of **head** and **tail bay** side walls, $\frac{1}{3}$ of breadth of lock for head, and $\frac{1}{15}$ of breadth in feet of lock, × greatest depth of water, for tail.

Large **counterforts** are necessary opposite the **hollow quoins.**

Versin of **lift wall** = $\frac{1}{7}$ of breadth of lock. The lift wall is built as a horizontal arch up stream under the head lock-gate. Thickness of the **floor** of head bay = 14″; length of apron = 20′ to 30′.

Floor of **lock chamber** is an inverted arch whose versin is $\frac{1}{15}$ of breadth, and whose thickness is from $\frac{1}{15}$ to $\frac{1}{3}$ of the breadth of lock.

194. Locks may be **founded** on timber platforms or hydraulic concrete.

195. Instead of locks, **movable tanks** or **caissons** may run on rails on inclined planes to connect two reaches of canal, each caisson holding water enough to float a boat; the caissons balance each other and may be driven by an engine, wire rope, and movable pullies.

196. Steamers may pull **themselves** up an inclined plane on wheeled cradles by fixed ropes.

197. Vertical lifts may be used with caissons instead of long inclines.

198. Canals are **supplied** with water from gathering grounds, springs, rivers, wells, reservoirs, and lakes, by conduits.

199. The **demand** may be **estimated** thus:—

Waste of water by leakage, evaporation, and repairs = superficial area of water × $\frac{1}{6}$ foot per day; **current** produced by leakage of lock gates = 15,000 cubic feet per day also.

Expenditure of water in passing a boat through a lock (called **lockage**) = lockful ± displacement of boat.

200. At a **single** lock, boats should ascend and descend **alternately**; where there is a **flight** of locks, the boats should ascend or descend best in **trains.**

201. Water may be **saved** at flights of locks by constructing **lateral reservoirs.**

202. If **flights** of locks are unavoidable, they should be made **double**; one flight for ascending boats, and one for descending boats.

203. Open rivers are such as are unobstructed by weirs.

204. The effect of **current** may be thus estimated: load drawn **against** current $= \left(\frac{3 \cdot 6}{3 \cdot 6 + v}\right)^2 \times$ load drawn **down** stream. v is velocity of current. (No. 10.)

205. A **canalized** river is one where weirs have produced a series of **navigable reaches**, connected by **river locks** in the ends of the weirs next the towing-path bank: river locks have no lift walls, hence the head gate and tail gate are of **equal height.**

206. With regard to **tides** it may be noticed that waves tend to **carry** sand, gravel, or shingle, **along a** coast in their prevalent direction if **oblique** to the coast; and to **heap** such materials up in bays and estuaries.

207. The **flood** tide in shallow channels is more rapid and stronger than the ebb tide, unless opposed by an adequate fresh-water current, hence the tendency of river mouths to silt up.

208. A **fresh-water current** if strong enough to hold its own channel, forms **a bar** at its extremity.

209. The chief object of **harbour engineering** is to manage to make the **ebb** tide more effective than the **flood**, so as to scour deep channels and remove bars.

210. Ordinary **spring tides** rise 18 or 19 feet.

211. For **groins, sea walls**, &c., see (III., 145).

212. Caution should be used in **reclaiming** land from the sea lest channels should silt up from the diminished scour, or harbours be injured; neglect of compensation works (No. 216), to provide against this, will result in damage, if not ruin of the channel.

213. The first act in **reclaiming land** from the sea is to run out a network of cross current wattled groins (III., 118), and longitudinal wattled dykes; this causes a deposit of **sediment,** and is called **warping.**

214. The land when **warped** as much as is practicable (213), is enclosed with sea dykes and drained.

215. **Training dykes** are constructed in estuaries to direct the ebb current upon a spot in the channel, where depth is to be maintained; they should not rise above the low water of spring tides.

216. **Bulwarks** or **quays** if erected should be **compensated** for by widening or deepening the channel.

217. **Piers** or **breakwaters** may concentrate the ebb current on one spot in a **bar**; when there is only **one** pier it should run from the **up-stream** side at the corner of the entrance: to decide which **is** the up-stream corner regard the direction of the **flood current** along the shore.

218. Tidal waters may be **stored** in a **scouring basin** at high tide, and let out **en masse** through sluices at low water to scour the channel. A velocity of **5′ per second** is necessary to clear away gravel and large shingle. A current of 5′ per second thus let run for

15 minutes at low water, confined by piers for **350 yards** only, has been felt at sea **2000 yards** off.

219. If masonry piers in the sea are founded on piles, the **timber work** should be **always** immersed.

220. Piers of **timber** or **iron** are best as a framework or skeleton pier, on screw piles. The posts of a timber skeleton pier may be left embedded in a loose stone breakwater.

221. A **deep water basin** is a reservoir in which water is retained to a level above half tide by lock gates opening **inwards**; it is surrounded by quay walls: if the entrance be exposed to storm waves, a pair of sea gates opening **outwards** must be added.

222. A deep water basin may be used as a scouring basin. (No. 218.)

223. A **dock** differs from a basin in having a lock at its entrance through which ships can pass in all states of the tide.

224. A **harbour lock** like a river lock (No. 205) has no lift wall.

225. The **entrances** to **docks** from a river channel should slant up stream of the river flow.

226. The best **gate** for a basin or **dock** is a **caisson** gate, or water-tight vessel of plate iron, which is floated into its place and sunk by running water into a tank at top: when the entrance is to be opened, the tank is run off and the caisson floated out into a recess.

227. It is desirable to conduct a supply of **fresh water** when attainable into basins or docks.

228. A **lighthouse** may be a round tower of masonry built of hewn stones dovetailed into each other, tabled, and dowelled; **solid** up to high-water level of spring tides, and high enough to carry the lantern clear of crests and reflections.

229. A **lighthouse** may be a skeleton frame of screw

piles and diagonal bracing supporting a platform and a timber or iron house. In this case the platform need only be high enough to clear natural unreflected waves.

230. The pressure of the **wind** must be considered also in designing a **lighthouse**; its maximum force recorded in Britain is 55 lbs. per square foot on a flat surface; in the tropics as much as 110 lbs. has been recorded.

231. For **sea walls** the stones must be laid in cement 2″ to 3″ inwards from the face. See (Stones, Masonry, &c.)

232. Indian rivers are frequently mere strings of detached pools in the dry season, and in the monsoon torrents 18′ to 20′ deep, running up to a velocity of 11′ per second, and scooping out sand to depths of 20′ to 30′.

233. A **drainage area** of only 15 miles by 10 has given a **flood** which rose over the top of arches 60′ span, undermined the foundations of the piers 20′ deep, and swept the whole away.

234. An **afflux** of 5″ water gives a **velocity** of 5′ per second, and is too strong for anything but rock. The **mean** velocity V, of a stream $= 0 \cdot 81\ v$, and the **bottom** velocity $= v \times 0 \cdot 62$; where v is the **surface** velocity.

235. The **best kind of groin** for regulating **water channels** is made of timber framework attached to piles as in (III. 70), floated out and sunk where wanted, until the desired alteration in the channel has been effected, after which the boxes with piles attached may be floated away and used elsewhere: always being firmly moored to the bank so as to drift in to shore in case of removal by violent floods.

236. The **velocity** of ordinary **floods** in India is

from 1′ to 4′ per second, violent floods from 5′ to 7′ per second, and unusual floods 8′ to 10′ per second.

237. In order to **limit** the **afflux** of the water to the maximum given in (No. 234), the proportion of obstruction caused by piers, &c., of a bridge, must not bear to the virtual section of the river a greater proportion than as below:—

For a mean velocity in feet per second ..	1	2	3	4	5	6	7	8	9	10
Proportion of obstruction allowable, in tenths of the river section	6	5	4	3	2½	2	1½	1⅓	1¼	1

These figures err slightly on the side of safety.

238. For **irrigating** land, if the water be near the surface the picottah (or *ye*tam) as it is called in Tamil, is used; one man walking up and down the beam will raise 400 cubic feet of water 11′ high in a day. The actual discharge is found per **hour** to be as below:—

			Cubic feet.		Gallons.
If raised 16 feet	by	picottah (requiring 1 man)	72·9	=	455·4
„ 5	„	baling (requiring 2 men) ..	300	=	1890
„ 40	„	charas (requiring 1 man, 2 bullocks)	149·5	=	924
„ 40	„	double charas	165·8	=	1045
„ 40	„	Persian wheel	69·3	=	429
		double Persian wheel ..	198	=	1242

239. Irrigation canals are carried along the **watershed** lines, and are supplied from a river as a rule; they follow the summit levels in order to command the irrigable land on each side by a flowing stream.

240. Navigation canals, on the other hand, should be still-water canals; they do not demand so large a supply of water, and so are cheaper at a low level.

241. The **Madras system** in India consists essentially in building a dam across the river at a suitable place,

say a narrow mountain gorge, thus damming up the water to a height from which it can be led off in channels to the adjacent fields.

242. In Bengal and the **North-west** the country is so flat that the rivers have no fixed bed in many places, but **easily shift** their courses; here the **heads** of irrigating channels are best placed in **still** water, or where there is a natural **backwater.**

243. If a **canal** has a **sluice** it should be placed at the **head**, else there will be a deposit of silt in the channel.

244. The **smaller** the **channel**, the **greater** must be the **slope** to maintain an uniform velocity: for main canals, 6″ per mile with a depth of 6′ to 10′, and a width of say 100′ would answer in light sandy clay; in proportion to such a main trunk, if the canal be reduced in its branches as to width and depth, the slopes must also be altered as below:—

Channel width.	Depth.	Fall in inches per mile.
80′	5′ 6″	6·4
60′	5′ 0″	7·0
40′	4′ 6″	7·9
20′	4′ 0″	10·3
10′	3′ 0″	14·8
6′	2′ 6″	19·5

245. Increasing the **depth** of a channel admits of a less fall in providing for a given velocity.

246. The **inclination** or slope is always given in **inches** per mile, the **velocity** in **feet** per second, the **discharge** in cubic feet per second.

247. **Silt** is the great **enemy** of canals, to avoid it the parent river is tapped as **high up** as possible near its source, or where it leaves the hills.

248. Where there is a large drainage area feeding a river, the **abstraction** of **water** for a canal is **not felt** lower down.

249. The **slope** of the **bed** is limited by deposit of silt and growth of weeds if below 1′ 6″ per second, and by tearing the bed and banks if above 3′ per second, or 2 miles per hour, in light sandy soil.

250. If for **navigation**, the minimum **depth** should not be less than 2′ 6″: the **width** sufficient to let two boats pass each other.

251. The following **formula** is found practically correct for waterflow:—

In open channels $V = \cdot 92 \sqrt{2\,d\,s}$,
where V is the mean velocity in feet per second,
d „ hydraulic mean depth,
s „ slope of the bed in feet per mile.

252. The **slope** of the **banks** may be assumed at 45° or 1 in 1, as the water will determine their ultimate angle of repose: the **ratio** of depth to **width** may be as 1 is to 14.

253. The first essential is a **good map** of the country; the next, a **network** of **levels** across the country from river to river, every 5 miles apart, connected by levels along the river banks: all levels reduced to the same datum line; from these the desirable lines of watershed for the proposed canal will be evident.

254. The **important points** to note on a canal survey are, villages, towns, channels, roads, railways, banks, remarkable buildings, quarries, wells, crops, trees, soil, &c.

255. Bench marks should be made at 3 mile intervals, and also close to every large watercourse, as well as at each end of every cross section; all **other** bench marks met with *en route* to be connected.

256. The **error** in any circle of **levels** ought not to exceed one foot per hundred miles; the best check is to retraverse the same stations with the same instrument, but in the opposite direction.

257. The **scale** for protraction of levels is 1 mile to 1 inch: for sections the **horizontal** scale is the same, and the vertical scale 100 times the horizontal scale: if other scales have to be used they should be aliquot parts, or multiples, of the standard **inch to the mile** scale.

258. Bench marks should be **sketched** on the margin of the sheet where they occur.

259. After the **watershed** line has been ascertained from the sections, a **theodolite traverse** including half a mile of country on each side, is made; on it are shown features of country, courses, ridges, swamps, buildings, wells, communications, gardens, with useful information about them. The chief point in the theodolite traverse is **accuracy.** The stations should be as **far apart** as practicable, never less than a mile, as the plotting and reading are more accurate in long station distances.

260. Stations are marked on the ground by pegs $3'$ long and $2\frac{1}{2}'' \times 2\frac{1}{2}''$ driven well home, on mounds; checks should always be taken to conspicuous fixed objects, trees, temples, spires, &c., and readings to the **minutest** accuracy the instrument admits of.

261. Where the **watershed** line cannot be adhered to, ground should be chosen such that the surface drainage can either be passed into the canal or diverted, else a swamp will form on the upper side of the canal.

262. A **moon** $2'$ diameter, of white calico, with a painted cross on it, stretched on a hoop, hoisted on two bamboos held by three guy ropes, forms a better station than a **flag**; the bamboos may be $50'$ long, tapered together at the top like a ladder.

263. The **ends** of curves and **central line** of canal must have **cubes of masonry** sunk in the ground; those along the central line may be $500'$ apart, and every alternate one numbered: they may be protected by mud

pillars; and the centre line and boundaries cut with a nick 6″ deep as they are lined out.

264. Canal embankments for a main trunk vary from 30′ to 100′ mean thickness.

265. Just as irrigation canals keep to the watershed line, so should the branch channels hold to the secondary ridges to command the country.

266. For **general convenience, bridges** may be built 3 miles apart if no roads occur to necessitate closer proximity, near villages they may have steps or gh*a*ts for bathing from.

267. For **over bridges,** 13′ headway must be allowed above the highest water level; the canal should be slightly **widened** where a bridge occurs, so as to neutralize the contraction caused by piers.

268. The **towing path** to be not less than 6′ wide under bridges, and may be 12′ to 15′ elsewhere, and 1′ to 2′ above the water level.

269. Roads along canals are useful for inspection, they may be 20′ wide, planted with **trees: trees** are much planted along canal banks, but they must not be within 30′ of the water's edge, else their roots interfere with the embankments.

270. When the country **falls** too rapidly for the **régime** of the canal (244·78), the point where the canal would have to be carried on an embankment is stepped or curved with an O G down to a lower level; and to break the force of a large body of water rushing over such a fall, a **cistern or reservoir** of water is left below to act as a cushion; besides which, a grating of strong timbers projects at the crest to retard the excessive rush over the fall; these timbers are tapered apart like the teeth of a comb, and supported on strong beams 12″ × 18″ section; the bars may be at their lower end 6″ × 9″, and at their upper end 3″ × 9″; the **bars** have

a **slope** of 1 in 3 upwards, and their ends fall 6″ short of the full water surface; the beams are set with their sides perpendicular to the slope of the bars, not vertically. The **rubbish** collecting on the bars is daily raked off and piled.

271. The **bed** of the canal must be **protected** by a first-class masonry flooring; tail walls, slightly converging, and backed by dry boulders of the same height as the tail walls, which slope 1 in 20 down stream from the high-water level till they vanish in the bed of the canal, help to direct the current and obviate back eddies.

272. The **banks** must be **revetted** with masonry down stream, and the bed flooring have a row of sheet piling at its lower end.

273. **A fall of level** may be met by a **rapid** or dry **boulder** floored **slope** of say 1 in 15, confined in 40′ squares by pacca masonry walling in cement. The **boulders** should be well grouted with hydraulic lime and shingle. Boulders weighing even 82 lbs. each, are **not** to be depended on at a slope of 1 in 15 when the velocity is more than 15′ per second.

273a. A **fall** increases the scour above it; to meet this scour a **masonry weir** is built on the crest of the fall, and its proper height is thus found:

274. If A be the sectional area of an open channel,
d, the hydraulic mean depth,
s, the length of slope to a fall of 1,
v, the mean velocity of current,
h, the height of water above the crest of fall,
l, the length of crest of fall, across the channel,
m, a coefficient $= 3$,
n, a coefficient $= 90$,

Discharge over fall $= m\,l\left(h + \frac{v^2}{2g}\right)^{\frac{3}{2}} = m\,l\left(h + \frac{n^2 d}{2gs}\right)$, where g is the force of gravity $= 32 \cdot 2$.

Discharge in open channel $= \mathrm{A}\,n\left(\frac{d}{s}\right)^{\frac{1}{2}}$.

And if the discharge over the fall is to be equal to that in the open channel

$$A\,n\sqrt{\frac{d}{s}} = m\,l\left(h + \frac{n^2\,d}{2\,g\,s}\right)^{\frac{3}{2}},\ \text{from which}$$

$$h = \left(\frac{900\ A^2\,d}{l^2\,s}\right)^{\frac{1}{3}} - 125\cdot8122\,\frac{d}{s}.$$

The **difference** between h, as thus calculated, and the actual depth of water in the channel, will give the height of the weir to be built on the crest of the fall.

275. The **depth** proper for the **reservoir** or cushion, below the fall, is

$$x = \sqrt{h} \times \sqrt[3]{d},$$

where x = depth of cistern,
h = height of surface of water above the fall vertically, measured from the surface of water below it,
d = the depth of water in the channel at full supply.

276. Canal **banks** require **protection**, say 300 feet below such a rapid as that described in (No. 273); boulder work, masonry, or piling, may be used.

277. Where falls occur, **locks** may be placed on one side in a bay adjoining the falls, or a separate navigable channel may be made **if necessary.**

278. A **size** of 100′ × 15′ is common on the Ganges Canal for **locks.**

279. If a **fall** exceeds 3′ in height, a separate channel may be cut as a mill-race, and a mill established for grinding corn. Such little mills as the **pan chakki** will grind 5 cwt. of flour in a day: they are built and farmed out by Government.

280. A **dam** is generally understood to mean an **open** dam; that is, one built in separate piers, which are generally 10′ apart, with spaces between them, which can be opened to scour the channel when wanted, or closed with stout planks, sleepers, or needles (III., 135). A solid dam is called a **weir.**

281. If the **river** be **navigable**, the **dam** must have

one or two 20′ wide openings, and **locks** built. If subject to sudden **floods**, flood-gates or **fall doors** may be provided. The **flanks** of a dam are best built as weirs, that is, solid; and a light footbridge may span the 10′ openings to connect the piers of the **dam** proper, which is called an **annicat** (*a*nei-kattu) in Tamil.

282. Escapes for sudden floods, owing to rain, or cessation of irrigation demand, must be provided to discharge **surplus** water into the natural watercourses; they may be placed every 40 miles, but the position of a good drainage channel or of dangerous places will determine the best site. They have openings precisely the same as dams have, and capable of being worked similarly.

283. Raj buhas are small branch canals with a masonry regulator at the head, from which the cultivators make their own water channels to their fields; their level should be as **high** as the full supply level of the main canal will admit of; that is, generally, 1′ to 3′ higher than the bed of the main.

284. The **slope** of a **raj buha** may (No. 244) be about 2′ per mile in light soil; falls may actually do good where two meet. They may be cleared of silt every April and October when the water is least required.

285. The **larger** a channel is, the **less** in **proportion** is the cost of maintenance compared with the revenue. No r*a*j buha should have a less width than 5′ at the head.

286. The system of **damming** up a channel to save trouble in raising the water must not be allowed.

287. The **normal section** of the bed is shown by lines of stakes driven in up to their heads right across the channel every furlong's length. Every bridge has a bench mark on its plinth, for reference.

288. Irrigation **outlets** (kol*a*bas) are tubes or pas-

sages of earthenware set in concrete with masonry ends $8'' \times 10''$ in the clear, delivering 2 cubic feet per second on an average; half kol*a*bas, $8'' \times 5''$, deliver 1 cubic foot per second. They tap the r*a*j buha close to the bottom, running under the banks. Lieut. Carroll's **module** provides a constant discharge under ever-varying pressures due to the fluctuating heads of water.

289. The **standard formula** for calculating **discharges in closed** channels and under pressure is,

$$D = \frac{2}{3} m l \left\{ (h + p)^{\frac{3}{2}} - p^{\frac{3}{2}} \right\} \sqrt{2g},$$

where D is the discharge in cubic feet per second,
m, constant of contraction $= 0 \cdot 6$,
l, length of measuring outlet in feet,
h, the height of the measuring outlet in feet,
p, head of pressure in feet, above upper edge of outlet,
g, the force of gravity $= 32 \cdot 2$.

290. On **sanitary grounds** no water is allowed to be issued for autumn crops nearer than

5 miles from a military station, or than					
1 mile	„	native town over		10,000	inhabitants.
½ a mile	„	„	„	5,000	„
¼ „	„	„	„	1,000	„
200 yards	„	smaller village.			

291. The waters of large rivers flowing on beds of pure **sand** with slope of 3′ 6″ per mile may be advantageously and cheaply dammed up for **irrigation,** but the whole bed of the river above the dam will be raised to the level of the crest unless effective **escapes** be provided in the banks of the river (282) to obviate this disadvantage.

292. With a vertical **fall** of 6 feet in rear of a **dam,** a **thickness** of flooring equal to 2′ of brickwork, covered by 1′ cut stone masonry, with a breadth to the rear of 21′ to 24′, has been proved sufficient in a pure sand-bed; protected by a mass of loose stones 9′ wide and 4′ deep, these **proportions** are good.

293. The main **security** of the **dam** depends upon the construction and maintenance of the **apron,** which should be in thickness $\frac{1}{2}$ height of dam, and in width down stream $3\frac{1}{2}$ times that height; the mass of loose stones requires constant renewing. (292.)

294. Irrigation from **wells** begins to "languish" when the water is 25′ below the surface, say in the plains of the Panj*a*b at a distance of 5 or 6 miles from the river; at 25 to 30 miles distance, the well water is 55′ below the surface..

295. The **indications favourable** to the construction of a **tank** or reservoir for irrigation of the land lying below it are (1) an ample supply of water; (2) a suitable bed dipping towards the gorge where the bank would be made; (3) accessibility of the land to be irrigated from it; (4) suitable soil and foundation; (5) accessibility of building materials and water for its construction.

296. The **returns** of such a work should be **compared** with its **cost** before recommending its construction.

297. A portion of the **band** or bank itself may be built of **solid masonry** up to 3′ of the level of the bank crest, and stepped down to an apron acting as an **escape,** overfall, or waste weir. Such masonry must be thoroughly good, and founded on firm soil or rock. If this be not met with at a moderate depth, an artificial foundation of concrete or rubble masonry must be substituted.

298. The **water slope** of an **earthen** embankment must be **protected** by a thin wall of pacc*a* brick masonry, dry stone pitching, wattling, piling, or turfing, where there is a **current.**

299. The common practice of locating **tanks** in **command** of each other in the same valley is dangerous,

as the breach of the higher tanks rapidly entails that of the lower ones. Breaches generally commence from the washing away of the earthen crest by rain and spray caused by high wind. The crests, therefore, require active supervision, and repairs should never be postponed till the case becomes dangerous. The natives themselves give timely arzis, when repairs are wanted, on sudden occasions.

300. Surplus sluices are to tanks what **escapes** (282) are to canals, or what safety-valves are to a steam engine. If they open at the **bottom** of the tank they admit of **scouring** out the bed to a great extent; the bed without this help would gradually fill up.

301. The **standard formula** for water **discharged** over a **waste weir** or calingula (kalingal in Tamil) is as below:—

$$D = 5\,l\,d^{\frac{3}{2}},$$
$$V = 5\,\sqrt{d},$$

where D is the discharge in cubic feet per second,
V, the mean velocity in feet per second,
5, a constant deduced from experiment,
l, the length of weir crest,
d, the height or depth of water on the crest.

302. Sluices of **irrigation** are long culverts or tunnels of brickwork or masonry in cement; arched or slabbed over, and passing through the banks of tanks on a level with the bed; they are provided at the end inside the tank with a chamber, in which is a covered outlet through a conical hole furnished with a plug, by means of which contrivance the supply can be regulated; at their other or outer end there is a chamber, the walls of which are pierced at various levels to suit the elevations of the fields to be watered.

303. As a tank gradually **silts** up, it is less expensive to **raise** the **banks** than to dredge or excavate again to its normal bed.

304. In calculating the necessary size of a tank in India for (nanjei or) wet cultivation, allow one **cubic** yard of water for every square yard of surface to be irrigated, as a storage volume; and for every square mile irrigated at a current velocity of 1 mile per hour, allow 8·3 square feet sectional area of discharge orifice.

305. In **embanking land** out from river **inundation**, the locality, cause, and amount, of the damage are to be considered in deciding what steps to take in order to meet the case; a top width of 6′ to 10′ is generally sufficient; the height of crest is found by adding 3′, for safety, to the difference of water level, or rise of the water in floods, and to the height of the observed flood level; this gives the total height for the embankment. If a **road** is to be added it should not be on the **top** but on the land-side slope of the embankment.

306. A **dock wall** may be 29′ high; **face curve** if not given a **straight batter**, may have a radius of 72′ from a centre level with the top of the wall: thickness of wall uniform 6′; **counterforts** 3′ × 3′ at 18′ intervals.

307. For a wall 22′ high the **thickness** at top was 3′ 6″, at bottom 7′ 6″; **counterforts** 1′ 6″ **thick** at top, 7′ 6″ **thick** at bottom.

308. Vertical backing for a **sea wall** 30′ high, top 7′ 6″, bottom 15′ thick, batter 1 in 12; **counterforts** 15′ wide and 36′ from centre to centre apart. See (III., 213).

309. Dovetail joints are the best for such masonry works; cramps run with melted lead, cast-iron dowels, and other means of binding the work (IX., 93), are by no means superfluous, as the frequent destruction of sea walls testifies.

316. In the side walls of Locks, **recesses** are made to allow the gates to swing well back when open. **Culverts**

having a well or fall at their upper end admit the water from the upper pond into the lock chamber: from the lock chamber sluices or paddles permit the egress of the water down to the lower pond; **these** openings may be formed **in** the gates themselves below the level of the lower water; but in the upper gates such openings are inadmissible, because they would form a cascade over the breast wall which would endanger the flooring, &c.

317. The **conduits** from the upper pond into the lock chamber should enter separately one at each side rather than discharge themselves through the breast wall. The conduits are not sloped but have a **well** or fall at their upper end, both to **cushion** the fall of the water and to counteract its progressive or forward force.

318. The **paddle** or **sluice** is usually made of **cast iron** sliding up and down in a rebated frame secured to a wooden frame built into the masonry for the conduit, or fixed in the gate itself at the down-stream end or **tail** of the lock.

319. **Paddles** or **sluices** work on a screw by rack and pinion gearing. The **area** of a **sluice** is found from the following formula given by **Du Buat** and quoted by all subsequent writers on the subject:—

$$V = (\sqrt{r} - 0\cdot 1) \times \left\{\frac{307}{\sqrt{s} - \frac{1}{2}\,\text{Nap. log.}\,(s - 1\cdot 6)} - 0\cdot 3\right\}.\,W t,$$

where V = the mean velocity of canal stream in inches per second,

r = the hydraulic mean depth in inches,

s = the length of slope whose height is unity = cosec. i, i being the angle of slope of the canal bed,

W = the **water pressure** on the sluice = the weight of a column of water whose transverse section is equal to the area of the sluice, and whose **height** is equal to the **depth of the centre of gravity** of the sluice below the surface of the water,

t = quotient found by dividing the area of canal by the area of the sluice.

320. The **formula** given above, namely,

$$V = (\sqrt{r} - 0\cdot 1) \times \left\{ \frac{307}{\sqrt{s} - \frac{1}{2}\,\text{Nap. log.}\,(s - 1\cdot 6)} - 0\cdot 3 \right\},$$

is **adopted** as the standard for calculating discharges in **open channels.**

321. The **hollow quoins** are the upright circular **grooves** cut in the side walls with the greatest accuracy for the **heel post** to turn in without leaking; they are of large stones joggled together, or better of cast iron.

322. The **heel post** turns upon a **gudgeon** revolving on a step of cast iron or gun metal set and bedded in masonry: the upper part of the heel post is embraced by an iron collar or strap, which is carried back by anchor straps into the side walls, and there secured into holes and run with lead.

323. The **posts bounding** each **leaf** or flap of the lock gate on the edge opposite to the heel post, are called the **mitre posts**; they abut edgeways against each other when the gate is shut.

324. Both **lock** and **dock gates** are framed either of timber or of iron; the heel and mitre posts are connected by horizontal rails, the whole being firmly braced and bolted together; the gate is then clad with diagonal planking on its up-stream side; the mitre posts must come truly to the angle of the mitre sills; if made of iron they must have a **ribband** of timber to deaden shocks, these timbers would be bolted on to the iron framing.

325. The **upper bars** or rails in **canal gates** are usually prolonged some distance beyond the heel posts, to act as levers in opening the gates; the ends are loaded to act as counterpoise weights and relieve the heel-post collars of excessive strain; for the same purpose rollers are also introduced below the bottom bar or

rail of the gate frame. These rollers may consist of fluted cast-iron wheels running on a rail laid upon the platform, and curved from the mitre angle to the side wall recess.

326. Large gates may require crab gear and chains attached to the mitre posts at $\frac{2}{3}$ of the depth of the gate to open them.

327. The **best angle** for the **mitre sills** is 135° at their **salient angle**; if the salient angle is **less** than this the gates will be unnecessarily **heavy**; if greater than this the resolved part of the water pressure, which acts laterally, will be excessively trying to the **side walls**, and the **heel posts** will be apt to jamb in the **hollow quoins.**

328. The portions of the **upper** and **lower ponds** immediately adjoining the upper and lower gates of the lock, and just **outside,** therefore, of each, are called the **head bay** and **tail bay** respectively; the walls of these generally splay away out to the natural width of the canal.

329. It is usual to have **waste weirs** for flood waters, and to conduct water from the upper to the lower reach or pond, without necessarily passing it through the locks. The **weir** must rest on a firm foundation. A row of **sheet piles** may be driven on the land side of a **stout timber sill** laid along the banks level with the water; from this a paved masonry channel may conduct the water down to the lower pond.

330. Sometimes a **masonry wall** takes the place of the **timber sill**; it must be coped with stones **cramped** together, and laid in hydraulic morter: if the **weir** is on the towing-path side, the water must pass under small arches or flat-topped drains below the path.

331. A **flight** of **locks** wastes more water, but is cheaper to construct, than an equal number of isolated

locks, as portions of the masonry may be dispensed with in a flight.

332. The **best lift** for a lock is 7′ or 8′; the **lift** should never be less than 5′ or more than 15′. The length of a **chamber** depends on the size of the craft for which it is designed, but should never be so small that there is any danger of **grounding** a boat by drawing off the necessary amount of water from one chamber to raise the level in the chamber below it sufficiently to float the boat from one into the other.

333. **Stop gates** are provided at intervals in long reaches, so as to admit of short lengths being laid **dry** for **repairs** without draining off the whole of the water in the reach; the gates are placed **at contracted** points.

334. If a **canal** is to join a **river** and there is a **bar** in the river, the junction should be placed below the bar: the gates should be pointed up or down according as the canal is above the action of tides or not.

335. **Towing paths** are made just like roads, they drain down into the canal; the bank should be revetted with stone, timber, or fascines one foot above and below the water level.

336. **Streams** running **across** the direction of the **canal** may be passed by ordinary culvert, by over or under siphon, according to their size and level.

337. The most **valuable streams** to the engineer are those which flow on an **impermeable** soil running down into valleys.

338. To form a **stream gauge** the banks should be 2′ high or so above the water level; dam up the water to a **notch board** placed across the stream at the water level; a vertical gauge rod is attached to this notch board; the zero is at the original water level or upper edge of the notch board.

339. A good and usual form of **notch** is 1″ of depth to 2″ of breadth; if no place can be found with banks suitable for a **notch board**, a long straight reach must be chosen, and the mean cross section and mean velocity measured there, whence the discharge can be found. (I., 86.)

340. For the size of **storage reservoirs**, calculate that $\frac{1}{2}''$ rainfall in a day on an acre, gives 1815 cubic feet = 12,344 gallons, and weighs 1815 × 62·5 lbs. 12,344 × number of acres in the catchment basin and divided by the number of minutes in a day of 24 hours, or 1440, will give the discharge in gallons per minute due to the rainfall on that area.

341. Or, the number of acres in a catchment basin increased by $\frac{1}{4}$ = discharge per minute in feet cube.

342. The average demand for a town **supply** is from 20 to 24 gallons per inhabitant per day. For a **two months' supply** therefore the reservoir should contain

$$n \times 20 \times 60 \text{ gallons or}$$
$$\frac{n \times 20 \times 60}{6 \cdot 5} \text{ cubic feet,}$$

where n is the number of inhabitants.

343. Peat soil being compressible, must always be removed from the site of a reservoir, but it may be advantageously **used to tamp the crevices** in the banks.

344. The **banks** of a reservoir may be faced with stone masonry in hydraulic cement, backed by **morter**, not **immediately** by rubble, **then** a rubble wall, then a puddle wall of clay and sand well poached, with its base in the impermeable soil below the bed.

345. Over the **peat** bed a layer of coarse gravel 15″ to 18″ thick might lie, over the gravel again a rough stone pitching 2′ thick; stones set on edge, and rubble masonry.

346. **Water slopes** of the banks have been made $2\frac{1}{2}'$ to $1'$ for a depth of $20'$, and beyond that depth $3'$ to $1'$; the **land slopes** were $2'$ to $1'$ for $20'$ deep, and below that $2\frac{1}{2}'$ to $1'$.

347. The **embankment** might be $12'$ **wide** at the top, the **joints** filled with **oakum** and Roman cement.

348. The **diameter of a pipe** to discharge a given quantity of water in cubic feet per second is thus found :—

$$D = \sqrt{\frac{l + q^2}{h}};$$

where h = the head of water in feet,
l = the length of pipe in feet,
q = the quantity of water to be discharged in cubic feet per second.

349. **Naked porous rock** is not admissible on an intended **gathering ground** for water, however well the other local features may suit such an arrangement.

350. A **river** has a fixed **regimen** when the relations of the cross section, slope, bed, and volume of water are invariable.

351. **Floods** arising from **rain** on the **catchment** basin are called **freshes.**

352. In designing improvements for regulating either the bed or banks of a river, the river may be advantageously considered in three sections, *viz.* the **sea proper** section, the **tidal range,** and the **river proper**; the engineer will require information as to the width, depth, and nature of bed throughout.

353. The best means usually of clearing a soft bed is the **steam dredge,** for which see (III., 73 to 76).

354. **Subsidiary channels** may be closed at their head by gravel dredged from the main channel; when the current is sluggish and tortuous through sandbanks, rubble walls may be advantageously applied in general;

the tops of river walls should be 3′ to 5′ above low-water level.

355. Mr. Smeaton considers it **most hazardous** to construct a high dam on a rapid river. Should one be **necessary,**

(*a.*) **Side channels** are to be made so that the river may not overflow the weir whilst in course of construction.

(*b.*) **A time** to be chosen when there is little water in the river.

(*c.*) **A place** to be selected where there is an island already, or suitable land for side channels exists.

(*d.*) The **weir** to be planned **oblique** or slanting, never square across the stream; and to be placed at the **lower end** of a **pool,** just **above** the rapid, never just below it.

356. Sluices, needles, fall doors, and many other forms are adopted for openings to permit the water to pass over a **weir,** or through it; some of these **swing** horizontally, others **revolve** vertically, most, however, **slide** vertically in grooves, being worked by rack and pinion gear with a catch.

357. River water may be filtered so as to deprive it of colour, taste, and smell, by passing it through sand, gravel, and charcoal.

358. If water is not only **mechanically mixed** with substances but **chemically** impregnated by **combination** with foreign constituents, saline, animal and vegetable impurities, filtering may not be sufficient to render the water fit for drinking.

359. The most usual impurities are **earthy salts,** *viz.* of **lime** and **magnesia**; salts of **iron** give a yellow tint and an inky taste.

360. All **reservoirs** for **unfiltered** water should be tapped at about 1′ below the surface by pipes having

flexible ends floated to that depth in a wooden float box protected by a wire netting from the entrance of weeds, &c.

361. Reservoirs must **not** be large enough to allow the water to **stagnate**; it is well to cover the reservoirs over when practicable.

362. Opinions are so extremely various as to the efficiency of **filtering**, that the only guide is actual experience in each case; for instance, in the project for supplying the Fort at Calcutta with drinking water from the river, the following statistics were gleaned through the kindness and courtesy of the chief engineer E. India railway, and others.

363. The great point is to have a large **settling reservoir** in two parts, **before** you filter.

364. Letting the water **rise** through charcoal answers very well on a **small scale**, as is done at Raneegunge, but not on a large scale; any kind of charcoal is used.

365. The chief engineer holds that the water is quite fit for drinking at Howrah; it rarely requires filtering at all, but is often pumped direct from the first settling bed to the tank on the top of the engine house; sometimes during the high tides it is brackish and has to be filtered, but it is quite good to drink, though there is a little chalk in it.

366. Another authority says the water is **not** fit to drink; if filtered through charcoal he thinks it **might** be; water is so filtered at Raneegunge; here it is merely filtered through sand and gravel for engine purposes.

367. The project was eventually set aside, owing to the medical authorities protesting against the use of the water, **filtered** or **unfiltered**, for drinking.

368. The **filter** at **Howrah** is cleaned once in three weeks about, by taking out everything, down to the

perforated tiles at the bottom, and cleaning them all. The interval will depend on the state of the river; but they know when the filter wants cleaning by the tardiness of percolation.

369. The **walls** of the **settling bed** at Howrah are 8′ high, 3′ thick at the top, and 4′ thick at the bottom.

370. The best arrangement of the filtering materials in general is,

12″	layer of	fine sand,
12″	,,	coarse sand,
12″	,,	gravel,
12″	,,	large pebbles,
3′ 0″ to 5′ 0″	,,	charcoal.

If **pumping** is not used, the materials may be **banked** upon each other at a **slope**, and the water passed through **laterally** instead of vertically, thus diminishing the excessive height necessary to filter through such a thick stratum; open **slabwork** 1″ open joints, or **perforated tiles** may underlie the strata of filtering material.

371. Such filters are **cleaned** from mere mechanical impurities by scraping off the upper half inch of the covering material.

372. A filtering area of 12,000 square feet will pass 6 million gallons in 24 hours, or 400 gallons per square foot under a pressure of 12′ head of water, or 200 gallons per square foot under 4′ head of water.

373. A **pipe** 3″ diameter and $\frac{1}{4}$″ thick will bear a pressure of 1000′ head of water. A pipe 6″ diameter would have to be $\frac{1}{2}$″ thick to bear the same. A pipe 1′ 3″ diameter and $\frac{5}{8}$″ thick will bear 500′ head of water. A pipe 2′ 6″ diameter and $1\frac{1}{4}$″ thick will bear 500′ head of water, too. If 1″ thick, 400′ head; if $\frac{3}{4}$″ thick, 300′ head.

374. A pipe 3″ diameter and 2200 yards long, under

a head of 60′, discharges 2375 gallons per hour; and the discharge, cæteris paribus, varies directly as the square root of the head of pressure; therefore the same pipe under an 80′ head of water would discharge

$$\sqrt{60} : 2375 :: \sqrt{80} : 2743 \text{ gallons per hour.}$$

375. The discharge varies also directly as the square of the diameter of the pipe.

376. In still water a head of 80′ will sustain 80′; in running water, owing to **loss of head** by **friction**, &c., it will only sustain 75′ depth. The effect of **friction** is much greater in proportion with pipes of small bore than with large ones, for instance.

377. If a 3″ pipe, as in number (374), discharges per hour 2375 gallons, a 6″ pipe would discharge $\frac{(6)^2}{(3)^2} \times 2375 = 9500$ gallons, and a 12″ pipe would give per hour 45,000 gallons, the head of water remaining constant throughout.

378. Water discharged vertically upwards will rise to **half the height** it **would** have attained under the same head of water had the pipe been prolonged. See (No. 376).

379. It is a good arrangement to construct an **equilibrium reservoir,** into which an engine may steadily pump the daily supply, working all day, instead of multiplying the horse-power necessary by pumping it all in the morning (when the maximum consumption takes place) as it is wanted.

380. In **mains** (of 9″ diameter) there should be (6″) plugs, at 50 yard intervals.

CHAPTER V.

CARPENTRY, CENTERING, ROOFS, FLOORS, STAIRS, TIMBER, AND WOOD WORK.

1. **Exogenous**, or **timber**, trees are those that form **successive rings** annually, the sap ascends in the exterior of the wood and descends by the interior of the bark which covers it; in **descending**, the sap forms new wood and bark.

2. **Endogenous** trees, like the Palm, have fibres indistinctly traversing each other, and **no successive** rings.

3. **Exogenous**, or **timber**, trees are divided into **pine wood** and **leaf wood**; or Cone trees, and all others.

4. The **circulation** of the sap is suspended in India during the dry season, and in Europe during the **winter**.

5. The **texture** of wood is **cellular**, consisting of minute cells, and fibres or tubes, **vascular**; when wood is sawn across the grain, in the centre is the pith (cellular tissue) enclosed in the medullary sheath (vascular tissue), with radiating partitions of cellular tissue called medullary rays.

6. When the medullary rays are large and clear, the texture is called **silver grain.**

7. Bundles or fascicles of **vascular** tissue forming the woody fibre lie between the medullary rays.

8. **Sapwood** is the outer portion of the tree, softer,

lighter, and weaker than the **heartwood**, which is older and inmost, being generally marked off distinctly from the sapwood.

9. **Heartwood** is alone admissible where strength and durability are required in carpentry.

10. **Knots** are distortions of fibre caused by the sprouting of branches.

11. The chief **pinewood trees** are: pine, fir, larch, yew, cedar, juniper, cypress, cowrie.

12. The chief **leafwood trees** are: oak, beech, alder, plane, sycamore, chestnut, ash, elm, mahogany, walnut, teak, poplar, box.

13. **Pinewood** is good for direct pull, transverse load, or planking; bad for shearing stress or thrust.

14. **Signs** of good **sound** timber, are **narrowness** of the annual **rings**, denoting slow growth, **clean cut**, without wooliness or clogging the saw. **Dark colour, heavy** weight, **little** resin or sap in the pores, **little** sapwood.

15. **Signs** of **bad** or **unsound** timber are **clefts**, or **radiating** cracks. **Cupshakes**, or **circular** cracks between the rings. **Upsets**, or crippled fibres. **Rind galls**, where a ring has been injured and a subsequent growth has covered it. **Hollows** and **spongey** places, indicating incipient decay.

16. **Pinewood**, the best sold in the market is from Norway, in logs $13'' \times 13''$ for straight beams, straight ties, frame work, and spars of ships. American Pine is larger and lighter, but softer and less durable than Norway Pine.

17. **White fir**, or deal, is from the spruce fir; the best kind is Christiana deal. It is sawn up into **battens** 7″ broad, **deals** 9″ broad, and **planks** 11″ broad, for planking, framing, and joiners' work: all the above scantlings are usually **12′ long** in the market.

18. **Larch** is strong and durable, used much for railway sleepers: the remaining pine trees (No. 11) are durable, but deficient in strength.

19. Of **leafwood** trees the strongest is the **oak**, either **stalk fruited**, and leaves close to stem, or **cluster fruited** and stalk leaved. The **stalk fruited** oak is tougher, straighter, easier to work, and less liable to warp than the **cluster fruited** oak, which is more flexible, and bears shocks better.

20. **Signs** of bad **unsound** oak are thick rings, large pores, dull surface, and a foxey hue.

21. **Oak matures** in 100 years, and its average at that age is 75 cubic feet of timber per tree. It may be felled between the 60th and 200th years of its age. The timber contains **gallic acid**, which tends to preserve the timber, but **corrodes** iron fastenings.

22. **Ash** is suitable where toughness and flexibility are required; handles of tools, shafts, spokes of wheels, should be of **ash.**

23. **Elm** is the best of all wood for **piles** and planking **under water,** naves of cartwheels, shells of ships, blocks, &c.

24. **Teak** is the most valuable wood in carpentry, especially shipbuilding; it is strong, stiff, tough, and durable; the best comes from Malabar, Ceylon, Johore, and Java. Teak should never be tapped for its oil. Insects do not touch teak, nor does it corrode iron, unless the wood has been grown in marshy ground.

25. The **best soil** for trees is gravel mixed with sandy loam; the **worst** soil is stagnant **swamp.**

26. The **hardest** woods are teak, ironwood, ebony, lignum vitæ: less than 24″ girth is not called **timber.**

27. If **felled too early** the timber contains too much sapwood; if felled **too late** the centre decays. Oak is **mature** from 60 to 200 years old. Ash, elm, and

larch, from 50 to 100 years old; fir from 70 to 100 years old.

28. The best **season for felling** timber is when the sap is not circulating (No. 4). The bark should be stripped off the spring before.

29. Immediately after felling, the timber should be **squared** by sawing off four slabs.

30. **Seasoning** the timber consists in expelling the moisture, either by exposure, sheltered from the sun or high winds, and piled in open order, clear of the ground (for **carpenters'** work natural seasoning takes two years, for **joiners'** work four years); or by artificial seasoning.

31. It is a good plan to **steep** timber in **water** for a fortnight after felling, or to boil it 4 hours.

32. **Artificial seasoning** is performed by passing a current of hot air at a temperature of from 90° to 300° Fahrenheit, into the top of a chamber, and drawing off at the bottom by a flue; the higher temperature being for the thinner planks. The time required to season different thicknesses of plank at **12 hours only** per day, is as below:—

Thickness of plank, in inches ..	1	2	3	4	5	6	8
Length of time seasoning, in weeks	1	2	3	4	5	7	10

33. **Timber is durable** if kept constantly dry or constantly wet, but not alternately wet and dry: it should be well **ventilated** when in a building, not allowed to lie in contact with **morter,** as slaked lime decays the wood. If exposed to dry air, timber grows a fungus called **dry rot.**

34. **Oak** in a ship **lasts about 12 years**; larch and ash 7 years; pine, beech, or spruce fir, 4 years. Teak and saul are the most durable of Indian woods.

35. The best **preservatives** of timber are good seasoning and free passage of air around it. **Artificial**

preservation may consist of drying, and then coating with oil paint, pitch, or tar. **Dry rot** (No. 33) may be prevented by saturating the timber with copperas (sulphate of iron), **chloride of zinc**, or corrosive sublimate (bichloride of mercury).

36. **Sulphate of copper**, in 100 times its weight of water, may be driven through the longitudinal pores of the timber, from a raised tank, at a pressure or head of 40′ of the solution; this drives the sap before it.

37. **Creosote**, or pitch oil, under a pressure of 150 lbs. per square inch, is absorbed in quantity equal to $\frac{1}{12}$ the weight of the timber.

38. **Shearing** means the sliding of the fibres either along or across the grain.

39. The **weight** of timber varies from about 30 lbs. per foot cube **pine** to 74 lbs. ebony, or 83 lbs. per cubic foot **lignum vitæ**.

40. **Joints** are for lengthening **ties** by **fishing** or **scarfing**. The **fish piece** may be of iron or wood.

41. A **scarfed** joint is when the ends overlap each other. The **key** may be $\frac{1}{3}$ of depth of tie, and made with or without bolts or straps.

42. A **joint** may be both **scarfed** and **fished**, the ends of the iron **fish piece** being indented into the ties: the **sectional area** of the fish pieces should be together equal to that of the ties. The sectional area of the **bolts** should be $\frac{1}{5}$ that of the remaining timber. The bolts should be **square** instead of round.

43. The **length** of such a **joint** should be,

For oak, ash, elm, or *leafwood* ..	6 × depth,	3 × depth,	2 × depth,
For pinewood ..	12 × depth, if without bolts.	6 × depth, with bolts.	4 × depth, bolts and indents.

44. The above **joints** are for lengthening **ties**; for lengthening **struts** the abutting surfaces should be plane and perpendicular to the thrust, fished on all

four sides; or bearing into a socket or iron shoe; and if long, braced laterally.

45. The **joints** for lengthening **beams** are the same as for **ties**, except that oblique faces are inadmissible.

46. The **faces** of a **beam joint** should be **parallel** to the cross strain, not perpendicular to it.

47. When one beam **crosses another** and bears upon it, a shallow **notch** should be cut in the lower side of the upper beam.

48. When the **cross joint** has not vertical space for a notch, it may be **tenoned** into a **mortise**, cut in the side of the other.

49. The **shouldered tenon**, with a pin or screw added, to fix the tenon in the mortise, combines length or **steadiness**, with depth or strength. It is used when a post supports the **end** of a beam, and is made **on edge.** (114, XIII., 67.)

50. When a **beam crosses** a post, the post may have a shallow **tenon** to fit a **mortise** in the beam, or the beam may be **notched** with a longitudinal **bridle**, fitting into a groove in the top of the post. The easiest mode of making such a joint is to cut a triangle in the lower side of the beam, leaving a **bridle** in the middle, and fit the post to it.

51. A **strut** meeting a **tie** should have a shoulder cut with a bridle groove in it, and a notch and bridle in the tie; or a tenon on the strut, fitting into a mortise in the tie.

52. A **shoulder** may be half the depth of the rafter, and be cut perpendicular to the direction of the thrust.

53. A **tenon** at the end of a strut may be equal in thickness with that of a **bridle**, or $\frac{1}{5}$ the breadth of the tie beam.

54. A **king post** is a **suspending** piece in the

middle of a frame, from the junction of two struts or rafters. A **queen post** is a suspending piece in any **other** situation.

55. Struts may be **notched** into suspending pieces, or abut against a shoulder, or both combined.

56. A beam is suspended **to a king post** by a **stirrup** of iron; or suspending pieces may be made in pairs and bolted together, so that the rafter tops are halved together as usual **between** them, being cut square above to abut against the upper block, which is bolted between the pieces of the king post.

57. Fastenings in frame work may be by **trenails** or wooden pins, whose diameter is $\frac{1}{3}$ to $\frac{1}{4}$ the thickness of the planks connected by them (see No. 114); or by **nails**, which should be hand made, and in length $2\frac{1}{2}$ times the thickness of the plank to be nailed; if x be the length of a nail in inches, $2x^2$ = weight of 1000 nails in lbs. **Bolts** and **screw nails** are also used for fastenings.

58. Timber should always be **protected** from bolt heads by **washers** $2\frac{1}{2}$ to $3\frac{1}{2}$ times the diameter of the bolt; when bolts bear **obliquely** on timber the timber should be notched perpendicular to the thrust, or a bevelled washer cut to both directions may be interposed.

59. The **breadth** of an **iron strap** is generally 6 times its thickness, and is **increased** at the ends if there are **eye-holes.**

60. A **stirrup** is an iron strap to support a beam, or keep the end of a strut from slipping.

61. Iron may always be used for **ties** except in a timber bowstring girder; iron is connected with timber by **screws and nuts, eyes and bolts, slots and wedges, stirrups,** and **sockets.**

62. Where many **struts** meet at their ends, a **cast**

iron **socket** should be used; where there is tension, **wrought** iron **plates.**

63. **Iron** fastenings should be **protected** as described under iron.

64. **Ribs** may be built of timbers on edge bolted together, in lengths breaking joint.

65. The **transverse dimensions** of timber are called **scantlings.**

66. **Platforms** consist of planks resting on **girders,** or **joists,** which are cross beams over the main beams or girders.

67. The **planking** requires more frequent **renewal** than the joists, therefore it may be light, and the joists close.

68. **Planking** for a bridge is usually 3″ to 4″ deep if the joists are 3′ to 4′ apart. In **railway** bridges the **joists** should be directly below the chairs.

69. The **weight** of a dense **crowd** is taken at 120 lbs. per square foot, planking and joists 30 lbs., if a broken stone or gravel roadway 100 lbs.: total 250 lbs. per square foot.

70. To compute the **dimensions** of a **joist,** fix the **ratio** which the depth shall bear to the breadth first for stiffness, **then** compute the breadth for strength. These matters are all taken out in practice from tables, deduced from experiments with various woods. N(o. 105, XIII., 223 to 227.)

71. A very common rule in India for roofing is half the length in **feet** gives the depth in **inches,** and half this again gives the breadth.

72. When a **platform** has **both** girders and joists (No. 66), the planks may be laid **diagonally**; and it is a good plan to leave $\frac{1}{4}$-inch **open joints** in platforms for circulation of air.

73. **Roofs** having been framed, are next covered; the

covering is measured in 10′ squares—that is, 100 feet super., or by square feet.

74. The following **materials** are used for **covering** roofs; with the proper pitch, and weight per square foot corresponding to each.

Material.	Angle of pitch.	Weight per square foot in lbs.
Copper	4°	1·0
Lead	4°	7·0
Zinc	4°	1·5
Corrugated iron	4°	3·4
Cast-iron plates $\frac{3}{8}''$	4°	15·0
Slates	30°	5·0
	22° 30′	11·0
Tiles	30°	6·5
	22° 30′	17·8
Boarding $\frac{3}{4}''$	22° 30′	2·5
Thatch	45°	6·5

For the timbering of slated and tiled roofs add 6 lbs. per square foot; and for pressure of wind 40 lbs. per square foot, to the above weights.

75. Sheet copper is nailed on boards; sheet lead, zinc, iron, slates, and tiles, may either be nailed on laths or battens, or else on boarding from $\frac{1}{2}''$ to $\frac{3}{4}''$ thick; such **boarding** is close jointed and neatly finished at the hips and ridges.

76. The **battens** are nailed across the rafters; or **laths,** slender pieces of wood $1'' \times 1\frac{1}{2}''$ to $1\frac{1}{2}'' \times 3''$, are used instead.

77. Sheet iron may be nailed direct to the common rafters, and cast-iron plates screwed or bolted to the principal rafters.

78. The parts of a **trussed frame** roof are the **principal rafters**—say 5′ to 10′ apart, **purlins,** crossing them, notched on them (No. 47), and leaning against the blocks which are spiked down to the principal rafters. **Common rafters,** say 1′ 6″ apart from centre

to centre, spiked or nailed on to the purlins. The **purlins** may be 6′ or 8′ apart from centre to centre. The **struts** transmit the pressure of the purlins, which falls transversely on the principal rafters, to the king posts. The **tie** keeps the feet from spreading.

79. The **length** of **diagonal braces** may be in clear unsupported space 20 times one side of their transverse section, which should be square.

80. The simplest truss is a **triangle**, with a king **post**, if of wood, or a king **bolt** if of iron.

81. A **straining piece** is a horizontal piece in a trapezoidal roof. The straining piece may act also as the tie of a **secondary truss.**

82. **Diagonal braced girders**, and **lattice** girders, are sometimes made of timber, with or without two horizontal **booms.**

83. Timber **spandrils** have **vertical** struts, and timber **piers** may consist of posts, **raking** inwards, and connected at each joint by horizontal as well as diagonal braces; the distance of the braces apart should not be more than 20 times their diameter.

84. There should be no **tension** in any part of a foundation or pier footing.

85. Timber **centres** are used for constructing arches; the centering consists of parallel frames or **ribs**, 5′ to 6′ apart, curved and covered by transverse planks called **laggings**, upon which the archstones or **voussoirs** rest, while the arch ring is under construction.

86. The **centering** of an arch should not be **struck** till the solid part of the backing has been built, and the morter had time to set, or the adjacent arch carried up to balance its horizontal thrust, if in a series of arches.

87. In constructing an arch the **centering** should be **loaded** from **both sides** towards the centre **simultane-**

ously. The angle of repose for ordinary masonry being 30′, it follows that the centering is only pressed upon by the superincumbent mass included in an angle of 60′ from the centre on **both** sides.

88. The best method of **striking centres** is to have a platform supporting **iron cylinders,** which are hollow, 1′ diameter, 1′ high, and 10″ of depth full of dry sand. There are four 1″ holes at a height of 1½″ above the base of each cylinder, which are stopped with corks till the centre is to be struck; when the corks are taken out the sand slowly runs out, and the centering gradually settles, as each cylinder has the foot of one of the wooden blocks, which are wedged in under the **sill** of the centering, in it, resting on the sand and packed with plaster. (No. 96.)

89. Striking plates and wedges are best placed transversely, *i.e.* under a **row** of posts supporting the centering. Such an apparatus consists essentially of an upper and lower striking plate, separated by a **main** wedge which backs and suffers the striking plates to close together as soon as the **retaining** wedges are knocked out.

90. The **back pieces** forming the upper edge of the **rib** (No. 85) are usually **supported** at points from 5′ to 15′ apart: the support should be as direct and vertical as possible from the rows of posts called **piers.** Struts, if introduced at all, should be in pairs. If direct vertical support from piers be unattainable, **trussed girders** are the next best form of support. **Polygonal** framework is utterly unfit for centerings, being deficient in stiffness.

91. Striking plates are **on** the rows of piles or posts called piers, and the **ribs** are **on** the striking plates again.

92. A **rib** may consist of a **sill** or horizontal beam,

a series of **vertical posts** over the piers, a set of **horizontal braces** called **wales,** diagonal braces between posts, oblique struts to support intermediate points in the back pieces, and the **back pieces** themselves.

93. Pillars of brick in mud may be substituted for piles or posts, as piers for a **centering**: on the pillars either a simple **framework** of **timber** or brick may be built up and formed as to its upper surface in the exact shape of the intended arch intrados, and plastered.

94. For small bridges the **centerings** may be built **entirely of mud** instead of merely plastering the upper surface with mud, but in such cases the **centering** must be struck before the rains come on; should this be impossible, piles must be used instead of pillars for supporting the centres.

95. If **planking** is intended for **floors,** or where close joints are required, the edges may be feathered and grooved, ploughed, and tongued, or rebated and filleted.

96. The **sand boxes** of (No. 88) must be only full up to 2″ from the top; the feet of the posts must **not** fit tight to the box or they will burst it; if the interior size of the box be $18'' \times 9'' \times 9''$, that of the post should be $16'' \times 8'' \times 8''$ to allow play: the sand will not overflow under the pressure.

97. The **sand boxes** are **placed** under each sill as near as possible to the vertical posts, and being filled with sand (No. 96) the block is laid on the sand, clear of the edges. When the sand box is firmly set, the block is **wedged** up to the sill by two wedges, $20'' \times 10'' \times 2''$ tapered to 1″ in 20″ of length.

98. Centerings should be **slacked** a little as soon as the arch ring is completed, to compress the morter: certainly before the face walls and parapets are added;

four weeks to six weeks is a very usual allowance of time before finally removing the centering.

99. The **dimensions** for **scantlings** of all kinds are most readily taken out from Tables (XIII., 13). The ends in ordinary buildings are simply built into the masonry as stones would be, but for floor or ceiling joists a wooden **template** is laid and correctly levelled in the same manner as a wall plate, and may be $12'' \times 1''$.

100. To level the **wall plate**, a few scraps of stone, a trowel or two of morter and a slab of wood above, to which the wall-plate is nailed, are used; wall-plate may be $4'' \times 1\frac{1}{2}''$ to $6'' \times 4''$.

101. **White ants** and other destructive insects do not seem to attack **wood** when buried as railway sleepers are, if the line be in **use** and the wood therefore subject to the **disturbance** of concussion and vibration.

102. **Centerings** for **door** or **window arches** may consist of two ribs each, fastened together by laths nailed across and braced by three struts: each rib has one horizontal and three curved edged pieces of 1″ boarding with their ends halved into each other; the ends of the horizontal piece rest on the cornice or string-course, which projects 3″ from the masonry, or else upon posts placed for the purpose. Such centerings answer very well up to 5′ span, from 5′ to 10′ span the planks out of which the ribs are cut should be 2″ thick. The **laggings** may be 2″ thick, and have wedges underneath any that require to be adjusted; in length they should not project beyond the wall face. The centering is erected in the doorway just outside the door-frame. (XIII., 11, 57, 77.)

103. When an **arch ring** is completed, before the **centre** is **struck**, the backing should be stepped in and the haunches built up.

104. No **timber** is allowed within 4′ of a **flue.**

(XIII., 51.) Timber, if good, will **last** say 25 years, or allowing 3 off for repairs, 23 years in India. A good **shingle roof** will last 16 years; no sapwood should be used, as it lasts only 3 years or so in India; the seasoning would require 3 years if not artificially accelerated.

105. The following **scantlings** for **roofs** of pine wood are averaged from calculations in the **Roorkee Treatise,** for an ordinary tiled roof with a pitch of 28° say

Weight of roof covering	.. ..	41 lbs. per square foot.
Absorption of rain	.. .. ..	4
Extreme pressure of wind	.. ..	40
Purlins and battens	.. .. ..	7
Total carried	.. ..	92 lbs. per foot super.

The truss may have a king post up to 30′ span, and two queen posts beyond 30′ up to 50′ span.

Span.	Tie.	Strut.	King.	Rafter.	Proper Section if an Iron Rod be used as a Tie.
′	sq. in.	″ ″	″ ″	″ ″	″
15	12	3×3	3×3	$3 \times 4\frac{1}{4}$	·56
17	15	$3\frac{1}{4} \times 3\frac{1}{4}$	$3\frac{1}{4} \times 3\frac{1}{4}$	$3\frac{1}{4} \times 4\frac{5}{8}$	·65
19	18	$3\frac{1}{2} \times 3\frac{1}{2}$	$3\frac{1}{2} \times 3\frac{1}{2}$	$3\frac{5}{8} \times 5\frac{1}{8}$	·72
21	21	$3\frac{3}{4} \times 3\frac{3}{4}$	$3\frac{3}{4} \times 3\frac{3}{4}$	$3\frac{7}{8} \times 5\frac{1}{2}$	·81
23	24	4×4	4×4	$4\frac{1}{8} \times 5\frac{7}{8}$	·89
25	27	$4\frac{1}{4} \times 4\frac{1}{4}$	$4\frac{1}{4} \times 4\frac{1}{4}$	$4\frac{3}{8} \times 6\frac{1}{8}$	·97
27	30	$4\frac{1}{2} \times 4\frac{1}{2}$	$4\frac{1}{2} \times 4\frac{1}{2}$	$4\frac{5}{8} \times 6\frac{5}{8}$	1·00
29	33	$4\frac{3}{4} \times 4\frac{3}{4}$	$4\frac{3}{4} \times 4\frac{3}{4}$	$4\frac{7}{8} \times 7$	1·20

Above 30′ span a queen post truss may be used.

Span.	Tie.	Strut.	Straining Sill.	Queen.	Straining Beam.	Rafter.	Iron Rod for Tie.
′	″ ″	″ ″	″ ″	″ ″	″ ″	″ ″	″
32	$4\frac{3}{8} \times 6$	$4\frac{3}{8} \times 4\frac{3}{8}$	$4\frac{3}{8} \times 4\frac{3}{8}$	$4\frac{3}{8} \times 4$	$4\frac{3}{8} \times 7$	$4\frac{3}{8} \times 6$	1·78
34	$4\frac{1}{2} \times 6\frac{3}{8}$	$4\frac{1}{2} \times 4\frac{1}{2}$	$4\frac{1}{2} \times 4\frac{1}{2}$	$4\frac{1}{2} \times 4$	$4\frac{1}{2} \times 7$	$4\frac{1}{2} \times 6\frac{3}{8}$	1·89
36	$4\frac{5}{8} \times 6\frac{5}{8}$	$4\frac{5}{8} \times 4\frac{5}{8}$	$4\frac{5}{8} \times 4\frac{5}{8}$	$4\frac{5}{8} \times 4$	$4\frac{5}{8} \times 7\frac{1}{2}$	$4\frac{5}{8} \times 6\frac{5}{8}$	2·02
38	$4\frac{7}{8} \times 6\frac{7}{8}$	$4\frac{7}{8} \times 4\frac{7}{8}$	$4\frac{7}{8} \times 4\frac{7}{8}$	$4\frac{7}{8} \times 4$	$4\frac{7}{8} \times 8$	$4\frac{7}{8} \times 6\frac{7}{8}$	2·14
40	$5 \times 7\frac{1}{8}$	5×5	5×5	5×4	5×8	$5 \times 7\frac{1}{8}$	2·27
42	$5\frac{1}{4} \times 7\frac{3}{8}$	$5\frac{1}{4} \times 5\frac{1}{4}$	$5\frac{1}{4} \times 5\frac{1}{4}$	$5\frac{1}{4} \times 4$	$5\frac{1}{4} \times 8\frac{1}{2}$	$5\frac{1}{4} \times 7\frac{3}{8}$	2·39
44	$5\frac{3}{8} \times 7\frac{5}{8}$	$5\frac{3}{8} \times 5\frac{3}{8}$	$5\frac{3}{8} \times 5\frac{3}{8}$	$5\frac{3}{8} \times 4$	$5\frac{3}{8} \times 8\frac{1}{2}$	$5\frac{3}{8} \times 7\frac{5}{8}$	2·51
46	$5\frac{5}{8} \times 8$	$5\frac{1}{2} \times 5\frac{1}{2}$	$5\frac{1}{2} \times 5\frac{1}{2}$	$5\frac{1}{2} \times 4$	$5\frac{1}{2} \times 9$	$5\frac{1}{2} \times 8$	2·64
48	$5\frac{7}{8} \times 8\frac{1}{8}$	$5\frac{3}{4} \times 5\frac{3}{4}$	$5\frac{3}{4} \times 5\frac{3}{4}$	$5\frac{3}{4} \times 5$	$5\frac{3}{4} \times 9$	$5\frac{3}{4} \times 8\frac{1}{4}$	2·77
50	$6 \times 8\frac{1}{2}$	6×6	6×6	6×5	6×9	$6 \times 8\frac{1}{2}$	2·89

The **use** of giving these **proportions** is that a neglect of them caused the Loodhiana catastrophe, and would have caused another at Jhelum had not the timely but unsightly expedient of strutting from the floor been adopted. These proportions give the mean between weakness on the one hand and waste of material on the other.

106. In India **single-joisted floors** should **always** be adopted where there is more than one storey, or where boarded floors are used at all. The **flooring** should not be commenced till the morter is all thoroughly **set**, and the walls have completely settled.

107. In order to **deafen a floor** some of the bridging joists may be made deeper than their neighbours, and the ceiling nailed only to them, passing the intermediate joists intact.

108. When the **divisions** or **rooms** in an upper storey are **numerous** and smaller than those below, the partitions must be **framed** so as to carry the weight to the walls, or, at least, **avoid** loading the floors in a manner not calculated for.

109. In **setting out stairs** where the building has already been erected, measure the height between the upper and lower floor, make a sketch of the lower hall to ascertain what **doors** have to be avoided by the stair ascent, thence lay down the positions of the first and last risers, calculate the rise for each step, fix the **strings** and **newel**, lay off upon them accurately by a vertical rod the height of each tread.

110. The **breadth** of each **flier** will generally depend on the space available. The **best proportions** for ease are rise $5\frac{1}{2}''$, breadth, $12''$.

111. A **stair** may have **one newel**, into which the outer strings for the various flights will be tenoned at one end, and which will stand in the middle width of the

space occupied by the stair, for a **dog-legged** stair; or the turning may be **wreathed** for a **geometrical** stair.

112. The **landings** may be **quarter spaces** if half width, or **half spaces** if they occupy the whole width of the staircase; one quarter space may be a **landing,** and the other be occupied by three winders, as may suit the measurements and requirements of the case.

113. The steps from floors to **landings** constitute a **flight.** The **winders** at a turning are laid off on a line bisecting the flights, and curved in quarter circles for a geometrical, or one semicircle for newel stairs. This line traverses the centre of each step, and a straight line, therefore, drawn from the newel through the points marking the intended centre breadth will give the **splay** of the **winders.** (110.)

114. In the various **joints** necessary for such **framing** a **mortise** or **tenon** should be the whole width, and **one-third** of the depth of the pieces joined. A wooden **trenail,** for pinning the joint, should be round in section, and its diameter $\frac{1}{4}$ the width of the surface it pins. The best position for a trenail is in the middle of the tenon at $\frac{1}{3}$ of its length from the shoulder.

115. For **building** large **timbers** together into **beams,** the upper edge should be well **cambered** up in the middle to prevent **sagging**; the lower edge of the upper timber should be indented in to the upper edge of the lower timber, the indents being shouldered square to the shearing thrust, or the timbers may have their adjacent edge notched at 45° (better than square) for rectangular keys or joggles, well driven home, and wedged to resist the **shearing strain** at the surface of contact. The **joggles** should have their breadth equal to twice their depth, their total aggregate depth $1\frac{1}{2}$ time the total depth of the built beam. In all cases the timbers should be well bolted, or better **strapped**

together, simply **transversely.** **Oblique** bolts or straps have been suggested. If used they should splay outwards from below, but plain transverse straps are more appropriate to meet the strains at work.

116. If wood be either **Burnetized** or **creosoted** to preserve it, the same pressure is applied, say 120 lbs. per square inch, or it may be boiled in tar. The vessel consists of tubes of boiler plates, double riveted together at the joints. 68′ is about the maximum length ever used, and 23 loads may be saturated at a time in such a vessel. The Burnetizing process takes 3½ to 4 hours. The solution consists of 1 gallon chloride of zinc to 30 gallons of water, and may be used any number of times. About 33 gallons to the load must be absorbed by the timber. As much as 70 gallons of creosote **can** be put into a load. The time depends on the texture or grain of the wood. A man must always be at the pump, to force in fresh liquid as it is absorbed.

117. Table of **scantlings** for **flooring.**

Length of Span, in feet.	Girders, 10′ apart, 10″ to 12″ Bearing in Walls.		Binders, 4′ to 6′ apart, 4″ to 6″ Bearing in Walls.		Joists, 1′ apart.		Ceiling Joists, 1′ apart.	
	Depth.	Breadth.	Depth.	Breadth.	Depth.	Breadth.	Depth.	Breadth.
′	″	″	″	″	″	″	″	″
6			6	4	6	2	3½	2
8			7	4½	7	2½	4	2½
10	9	7	8	5	7½	2½	5	2½
12	10	8	9	5½	8	2½	6	2½
14	11	9	10	6	9	2½		
16	12	10	11	6½	10½	2½		
18	12	11	12	7	12	2½		
20	13	11	13	7½	12	3		
24	15	12						
26	16	12						
28	16	13						
30	16	14						

118. Boarding with **tarred seams** forms a light **roof** in hill stations: it is well to cover the seams, before dry, with laths and tar them over again; the tar should be

boiled with pitch to keep it from washing off with the rain.

119. Orophilite is a material composed of river sand and pounded chalk made into a paste with boiled linseed oil; this may be spread on one or both sides of common coarse cloth, hung up till dry, and laid over the roof for a covering.

120. Shingles may be made out of old **packing cases**, &c., the wood being usually **well seasoned** and fit for nothing better.

121. Roof girders may be made of **iron** (see VIII., 192).

122. For **timber bridges** and the scantlings of their various pieces, the same rules apply as for all other frames. It is well to tar the timber and cover the upper sides with sheets of well-tarred metal to ward off the effects of exposure to damp; asphalt will answer the same purpose.

123. For **spars** up to 40′ with a rise of $\frac{1}{6}$, the ribs may consist of five or six pieces of 3″ plank 9″ deep, abutting against each other, the joints being crossed and broken by other planks 12″ deep, all the planks being keyed and bolted together.

124. For **arches** of 200′ span, there might be four **ribs** composed of scantlings 9″ by 12″ steamed and bent to the required curvature; these are laid, two thicknesses in **width** and any number necessary in **depth**, say four or five deep, the joints being well scarfed, bolted, and keyed. The roadway timbers rest on supporting pieces notched on to the **ribs** in pairs and bolted together, at say 15′ to 18′ intervals. The roadway timbers for a paved road at such intervals of support might be four of the above scantlings bolted together supporting the roadway joists, on which are laid 3″ or 4″ elm planks close jointed, and over this the road metal.

125. Mere **multiplication** and **bracing** of such ribs will suffice, from 250′ up to 400 feet span.

126. Tredgold's rule for **abutments** to **timber arched** bridges is

$$T = \frac{\left\{\sqrt{\left(\frac{160\,h^2}{w\,R} + 1\right)} - 1\right\} s\,w}{120\,h}$$

$$A = \frac{b \times s^2}{R\,n} \times 0 \cdot 001.$$

h being the height of abutment,
w, the weight of a square foot of the bridge,
R, the rise,
s, the half span,
n, the number of ribs,
A, the sectional area of one rib,
b, breadth of bridge,
Rise the same as for masonry bridge.

CHAPTER VI.

CEMENT, CONCRETE, LIME, AND MORTER.

1. Pure rich lime is obtained by burning stones which contain no silicates in them; its characteristics are that it **slakes** easily, **sets** slowly in air, and not at all under water.

2. Hydraulic lime is obtained from stones containing 10 per cent. to 30 per cent. of silicates in them; it **slakes** less rapidly, and **sets** slowly under water.

3. Cements are produced from stone containing 40 per cent. to 60 per cent. of silicates; they do **not slake** at all, and **set** rapidly under water.

4. Puzzolana (terra) contains silicates in excess. The best **puzzolana** is mine dust, or silicate of alumina and iron; it may be made artificially by grinding or beating to powder bricks or burnt brick clay, in fact any process which gives a dry powder of silicate of alumina, or silicate of alumina and iron.

5. If **puzzolana** be mixed with pure fat **rich lime** it makes an artificial **cement**; 41 parts carbonate of lime and 59 of clay may be burnt together to form **cement**; or 1 of mine dust mixed with 2 parts **hydraulic lime** by volume, to make cement.

6. Chalk (carbonate of lime), calcined at a bright red heat gives 56 per cent. of fat rich lime; of this amount $\frac{1}{8}$ is generally wasted. Fresh burnt lime is called **quick-lime**, and when water is added to it it swells, gets hot, crumbles to powder and is then called slaked lime, or **slack lime**, being a hydrate of lime. Two parts of

shells mixed with 1 of charcoal are burnt in Madras for lime. Kilns may be, at bottom, 4′ internal diameter; at a height of 9′ 10″, 10′ diameter; and at the top, which is 23′ high, 6′ 6″ diameter; such a kiln would turn out 240 cubic feet of lime daily, as perpetual kilns.

7. **Quicklime** may be kept in air-tight barrels, else it becomes air slaked and is spoilt unless it be reburnt.

8. The **lime kiln** may be 10′ or 12′ high, with circular horizontal section and oval vertical section. The limestone is broken up into pieces about 3″ cube, mixed with one-fifth part of fuel thrown in layers and burnt.

9. **Hydraulic lime** is produced from stones containing **silicate of alumina**, and sometimes **carbonate of potash**: the stones are generally compact, grey, blue, or brownish yellow.

10. In order to **test** the **hydraulic** quality of lime, calcine two or three cubic inches in a crucible, make it into a stiff paste with water, roll into a ball, immerse in a glass of cold water; if the lime be **hydraulic** it will harden in twenty-four hours, if **cement** the ball will be finger proof in a few minutes.

11. The best **hydraulic lime** slakes so imperfectly that it has to be ground in a mill before water is added. In hydraulic lime, as distinguished from cement, there is a surplus of lime after combining with silica and alumina.

12. If cement be artificially made by burning together 41 parts of carbonate of lime and 59 parts of clay, a **double silicate** of alumina and lime is formed.

13. **Morter** consists of two parts of clean sharp **river sand** to one of fresh well-burnt stone **lime.** **Sea** sand keeps morter always wet by absorbing moisture from the atmosphere, unless it has been well washed.

Common morter may be made **hydraulic** by adding **puzzolana.**

14. Concrete is a mixture of **gravel** with **morter** in the proportion of 4 parts gravel, to 3 of morter. The ingredients should be mixed in a pug-mill **dry**, and the lime in fact **slaked in contact** with the gravel: instead of a pug-mill a lime grinding-stone may be used: and the concrete shot from a 10′ stage, in 12″ layers.

15. Beton is strong **hydraulic concrete** made of 1 part hydraulic morter mixed with 2 parts broken stone, angular, 2″ cube; the stones should not be smooth pebbles.

16. Mixed cement is composed of 1 part sand to 2 parts cement; it is used for **pointing** or **edging**, the admixture of sand is to prevent too rapid drying. (IX., 57.) Cement loses its tenacity by mixing with sand, in the proportion of $\frac{3}{4}$ tenacity lost by admixture with an equal volume or part of sand.

17. Gypsum is sulphate of lime; calcining it makes plaster of Paris; to form paste, the powder should be put into water, not water added to the powder.

18. Bituminous cement is made by mixing a pitchy substance with an earthy substance.

19. Asphaltic mastic consists of **mineral tar** (from shale) called **bitumen**, mixed with powdered **asphalt**; the **asphalt** being a bituminous limestone, or carbonate of lime, containing in its pores from 3 per cent. to 15 per cent. of bitumen. Common **coal tar** mixed with finely-ground limestone will answer.

20. Mastic, made of coal tar and finely-ground fire-clay, is excellent for water and acid tight joints.

21. Asphaltic morter consists of

$$\left.\begin{array}{r}\text{1 part bitumen} \quad \ldots \quad \ldots \\ \text{7 or 8 parts powdered asphalt}\end{array}\right\}\begin{array}{l}\text{asphaltic} \\ \text{mastic (No. 20);}\end{array}$$

$\frac{1}{35}$ part resin oil;
$\frac{3}{5}$ „ sand.

In order to make this asphaltic morter or **bituminous morter**—

1. Melt the bitumen;
2. Add the asphalt broken small;
3. Then the resin oil;
4. The sand: and if asphaltic concrete is to be made,
5. The broken stone; 11 parts morter, as above, to 9 of stone.

If too hard, add bitumen and resin oil; if too soft, add asphalt and sand.

22. Iron concrete is made of 17 parts of gravel with 1 of iron turnings spread in alternate layers; it is good for sea walls, &c.

Asphaltic concrete for sea walls, &c., may also be made of 2 parts asphaltic mastic (No. 19), 3 parts broken stone.

23. Limestone loses half its weight in burning, and lime gains twice its bulk in slaking. The quantity of sand which lime will bear depends on its quality; too much sand makes morter **set** sooner, want less water, get harder, crack less in drying: for a general rule from 2 to 3 of sand is a good proportion in morter.

24. In order to make **morter**, strew the quicklime on a stone floor when fresh burnt, pour water over it all until it will absorb no more; turn it over in a heap with a shovel and let it effervesce; next take three times as much clean sharp-grained river **sand**, cover the lime with it, let it slake till the heat subsides and the lime falls to powder: mix well with the sand and screen the whole well on a riddle to take out the **lime core**, or lumps of slack-burnt limestone; this process is called **larrying.**

25. If required for **plastering**, bullock's hide **hair** is mixed with the morter.

26. Shell lime gives a morter which sets quicker than stone lime; **chalk lime** has a great deal of **core.** (No. 24.)

27. Draw kilns are **perpetual** kilns, where the limestone is loaded in at the top and drawn off at the bottom. Bricks and limestone may be burnt simultaneously in the same kiln. Great economy results from conducting kiln operations on a very large scale, so as to keep them continually active when once heated.

28. Lime, if wanted **only occasionally**, may be **burnt** in conical kilns: layers of limestone broken into cubes of 3″ side alternating with coal, the whole may be covered in with sods and lighted at the bottom. **Quicklime** may be burnt over pots of sulphur confined beneath, this gives Capt. Scott's cement, admits of 4 parts sand, and is as hard as brick.

29. Even **turf kilns** with peat fuel may be successfully used for lime burning, but the **waste** of fuel is enormous.

30. The most important constituent in a **bridge** is the **cement**, the best is made of 1 part of stone lime to 2 parts of fine pounded brick, the ingredients should be mixed dry and ground together under a grinding-stone, then slaked with just enough water to make them into a paste. Fine gravel may be used instead of pounded brick, and the operations take place in the same order. The quality of the cement depends mainly on the lime being **slaked** from its caustic state **in** actual **contact** with the gravel or pounded brick.

31. The workmen should not be permitted to mix **large quantities** of **morter** and leave it wet on the ground, as they frequently do. Only as much as is wanted should be made at one time. 1 of **sand** to 1 lime should be the limit for hydraulic morter.

32. Artificial puzzolanas should **not** be used where exposed to **sea** water, or to water impregnated with **salts.** Soorki or pounded brick, if it contains a small percentage of lime in the clay, makes a better puzzolana

when underburnt. If, however, it contains **no** lime it makes a better puzzolana when thoroughly burnt.

33. A **mixture** of crude clay with $\frac{1}{9}$ part of **lime** and $\frac{1}{3}$ part water forms a paste, which hardens to resist the thumb in 3 days, and is insoluble under water. It should not be dried too suddenly, and would answer well for **flooring**.

34. A simple method of **testing stone for lime** is to observe its colour, which should be bluish grey, brown, or dark. It should **taste** of clay to the tongue, and smell of clay when wetted. It should only partially dissolve with effervescence when treated to dilute muriatic acid.

35. If the above **tests** are satisfactory, break the stone into lumps 1″ cube or so, put these gradually into a common fire, and keep them red-hot about 3 hours; take out a fragment, and **test** it with dilute muriatic acid. If it still effervesces it is not sufficiently burnt. If, on the other hand, it has been burnt to a darker colour, the burning was excessive. Having obtained a piece properly calcined, pound it in a mortar to a **perfectly** impalpable powder, mix the powder with $\frac{1}{3}$ its volume of water, roll it up into a ball with the fingers. If it is a good hydraulic cement it will harden rapidly.

36. Fat or pure **lime** remains as paste under water; **slightly hydraulic limes,** *i. e.* containing 12 per cent. in all of silica, alumina, magnesia, iron, and manganese, set in about 20 days under water, but in a year are only as hard as soap.

37. Hydraulic limes, from stones containing up to 20 per cent. of the above ingredients, set in 6 to 8 days under water, and in 6 months are as hard as soft stone.

38. Eminently hydraulic limes, containing up to 30 per cent. of the ingredients mentioned in (No. 36); they set in 3 days, harden in 1 month, and in 6 months

will splinter with a conchoidal fracture under a blow. (IX., 13.)

39. Hydraulic cements contain up to 50 per cent. of the ingredients in (No. 36). They set in a few minutes, and harden to stone in the first month.

40. Concrete, when used for **foundations,** must be made of **fat lime,** as there is danger of imperfect slaking if the lime be hydraulic in any great degree, in which case the mass might subsequently swell and crack.

41. The **strength** of **morter** may be best **tested** by building a beam of bricks, cemented side to side, and projecting out from a wall, adding one brick each day. Ordinary morter will sustain such a beam to a length of 30 bricks on edge or so. Both bricks must be wetted and spread with morter before application.

42. In order to avoid great expense **any** sand may be used in making morter; but **sea sand,** if used, should be well **washed.** The great point is to mix the ingredients thoroughly by beating and grinding them together.

43. The **admixture** of the coarsest **sugar,** called Goor in Bombay, and Jagiri in Madras, in the proportion of 1 lb. Jagiri to each gallon of the water with which the morter is mixed, **adds** one-half to its breaking strength, and **doubles** its **cohesive** strength.

44. In **applying morter** it is of the first importance that the surface be thoroughly drenched with water before the morter is laid on. (I., 89.) The morter should be as **stiff** as consistent with working, and should **not** be allowed to **dry** too **rapidly.**

45. Morter is much **damaged** by exposure to **frost** before it has set. The action of frost is severest at the ground level, therefore the foundation and basement in such cases should be laid in hydraulic morter or cement,

which set rapidly. During severe frost all building operations of this nature should be suspended.

46. Grouting consists of morter mixed with an excess of water, and poured as a fluid into the joints of the masonry. The lime should be strongly hydraulic. Equal parts of lime and puzzolana would answer.

47. Concrete may be made of small stones or rubble and sand mixed with fresh burnt stone lime, ground to powder without slaking, in proportions of 1 lime, 2 sand, 4 broken stone or gravel. The ingredients are thoroughly mixed dry before water is added.

48. If **hydraulic** lime be used, the lime is **slaked** before admixture with the gravel, and it sets **under water,** which concrete does **not.** In any case the ingredients should, when used for foundations, be well rammed home. If concrete is too fluid, and shot from a 10′ stage, there is danger of all the stones sinking to the bottom of it. (No. 14.) No stones to be larger than 2″ cube.

49. Burnt clay may be substituted for gravel in making **concrete** with great advantage where the relative transport or cost of materials suits. This is called **Jelli** in Madras, and broken bricks furnish the burnt clay.

50. Concrete or **beton** should be spread in 12″ layers, and rammed till they set, one layer setting before the next is laid on. If **beton** be used, the lime must be **ground** and well slaked **before** mixture. (48.)

51. It is better in building with beton under water to make it in large **blocks,** and let it set before lowering it into its place. Such blocks are moulded in large strongly-bound wooden boxes, and a tarred canvass casing to the concrete is useful to prevent the action of water. Sheet piling may even be added to avert scour if there be a current.

52. Not only **foundations** but **whole buildings** may be constructed of **concrete**, sea walls, church pillars, piers, **and arches** of bridges, but for such work the concrete should be very well made and tested. **Concrete** is peculiarly adapted for structures where dryness is necessary, under **flooring**, about cellars, magazines, casemates, and aqueducts.

53. Concrete bears four-storied houses without **crushing**. It is **cheap**, and easily made without skilled labour.

54. It is **necessary** to **plaster** a building only when built of underburnt bricks laid in clay or mud; or in the case of arched roofing and vaults, because unless plastered outside, damp would penetrate the very finest joints. **Interiors** of houses in India are always plastered.

55. The presence of **sand** in morter or plaster contributes nothing whatever to its properties as far as tenacity is concerned, but it diminishes the shrinkage in drying. Only **fresh** sand should be used, as **salt** would keep the walls always **damp.**

56. The **first coat** is scored diagonally with a trowel point while soft that the **second coat** may adhere better. The **morter** is the same as that used for building, say, 1 lime, 1 sand, and 1 lb. of ox hair or hemp added to 6 cubic feet of the morter. For an upper coat slack lime, with excess of water, is mixed with hair and no sand.

57. Wherever **gypsum** abounds it is used exclusively for plastering. It is called Plaster of Paris, quarried in blocks, burnt at a low heat, ground to powder and kept dry in casks, from the air.

58. Stucco is a kind of plastering worked to resemble marble. It is laid on in three coats; the various colours are obtained by mixing with the calcareous powder

gypsum and lime, certain metallic oxides; thus, oxide or carbonate of copper gives blue. Grey is made by mixing ashes—forge ashes, litharge, yellow oxide of lead, green enamel, are also used to colour it.

59. When the **stucco** is perfectly dry, **polishing** is commenced by rubbing the surface with a fine **stone**, washing it with a **sponge**, rubbing with a linen dipped in Tripoli powder and chalk, then with oil and Tripoli powder; lastly, with oil alone.

60. The **plaster** may well be tempered with sugar in the water (43); the first coat may be $\frac{1}{2}''$ thick; the second coat has no sugar, as it would tinge the colour; the third coat, if for very fine work, has $\frac{1}{7}$th of white sand added to the lime and drenched to a thick cream-like consistence: to every bushel of this, the whites of 11 eggs are added, half a pound of clarified butter and a quart of sour milk are added, or oil may be substituted for the butter and milk; the third coat is laid on **before** the second is dry.

61. Lime made from marble, coral, sea shells, white crystalline limestone and chalk, must not be exposed; it may be recognized by effervescing violently when treated with water, and it crumbles to powder in slaking: it will not set unless kept dry.

62. Dorking and **Halling limes** set better in wet situations than chalk limes do. Again, the blue lias limestone from Dorsetshire, the south shore of Bridgewater Bay, Aberthan, in Glamorganshire, and Whitby, in Yorkshire, contain still more clay, and possess therefore still higher **hydraulic** properties.

63. Rocks containing **lime** may be tested by breaking into small pieces and adding vinegar or dilute Hydrochloric (muriatic) acid, which will cause effervescence, according to the proportion of carbonate of lime present.

64. Blue lias lime will not bear more than 2 parts of sand to 1 of lime.

65. All the **requisite** water in slaking quicklime, and no more, should be added **at once, else** the lime will be **gritty.**

66. The **best sand** is **drift** sand, pit sand, or **river** sand, clean, sharp, and quartzose, free especially from clay and from salts, calcareous, gypseous, or soft matter, pyrites or heavy metallic matter.

67. To **cleanse sand,** provide two sieves, one with holes $\frac{1}{16}''$ in size; through this the sand is sifted in clear streaming water. What passes through is again sifted through a sieve, whose meshes are now only $\frac{1}{30}$ of an inch, and divided into **fine** sand and **coarse** sand, according as it passes through or remains on the sieve.

68. Stone lime should be used for **cement;** that quality is best which is freshest made, closest kept, dissolves in acetic acid with least effervescence, leaves smallest residue insoluble, and in that residue the least proportion of clay gypsum or marl.

69. To make **perfect cement** put 14 lbs. of fresh well-burnt stone lime into a fine sieve $\frac{1}{32}''$ meshes, made of brass, plunge this in a vessel of **soft** water, that is, rain or distilled water, moving it up and down so as to **impregnate the water** with **lime,** throw away the core or lime fragments which do not pass through the sieve, add more fresh lime, and continue the operation until as many **ounces** of lime have passed into the water as there are **quarts** of distilled water in the vessel. Place the **lime water** in a butt, let it stand till it settles; draw off from the **top** by **taps** placed at vertical intervals, as the lime subsides: the butt must be closely covered and the water quite free from saline matters.

70. On an enclosed clean surface spread fresh **quick-lime** and **slake** it by gradually sprinkling the **lime water** (No .69) upon it. It must **then** be sifted through the fine brass sieve (No. 69) and used **instantaneously,** or kept in perfectly air-tight vessels till used: it is now called **Purified Lime.**

71. Prepare **bone ash** by grinding the whitest burnt bones and **sifting.** Now take 56 lbs. of the coarse sand named in (No. 67), and 42 lbs. of the fine sand, mix them on a horizontal plank, spread the sand till it stands 6″ high, give it a flat surface, wet it throughout with the **lime water** (69) till it cannot retain more; to the wetted sand add 14 lbs. of **purified lime** (70), in successive portions, mixing and beating them well up together; then add 14 lbs. of bone ash, also in successive portions, beating well up together; the quicker the morter is mixed and used the better it will be; the above is called **coarse-grained cement,** and is used for pointing, plastering, or stuccoing.

72. The walls are to be well **wetted** with **lime water** (69) before applying the plaster, or pointing or stucco, and lime water to be used when it is necessary to moisten the cement or to facilitate floating. The **joints** to be **raked** out to a depth of $\frac{3}{4}$ inch.

73. For **fine-grained cement** take 98 lbs. of the fine sand (No. 67), wet it with the lime water (69) as before (71), mix it with the **purified lime** (70) and bone ash, as in (71), but add 15 lbs. of lime instead of 14 lbs., as used in making coarse-grained cement. This fine-grained cement is used for giving the last coating or finish to any work intended to imitate the finer grained stones.

74. If **cheap cement** is wanted, take a coarser clean sand, or well-washed fine rubble; to 56 lbs. of this add 14 lbs. of fine sand, mix them together and add 28 lbs.

of coarse sand, mix and saturate well with the lime water, add 14 lbs. of **purified lime** (70) and 14 lbs. of the bone ash, and thoroughly incorporate the ingredients.

75. White sand, white lime, and the whitest bone ash must alone be used if the colour is to be **white**: if **grey**, grey sand and half-burnt bones are used for the cement. **Coloured cement** is made by the admixture of coloured Talc in powder, or of coloured vitreous or metallic powders; any such durable ingredients as are used in painting will answer to colour cement.

76. Such **cement** will answer admirably for making artificial stone; the hard material should be mixed with the cement, as in making concrete, and formed in moulds to the size and shape of the intended blocks, which are subsequently exposed to the air to harden.

77. If exposure in wet situations be intended, $\frac{2}{3}$ of the prescribed quantity of bone ash is to be omitted, and an equal measure of **Terras** to be substituted; if the sand be not of the coarsest sort, more powdered terras must be added until the weight of the terras altogether shall be $\frac{1}{6}$ of the weight of the sand.

78. Roman cement is made from "Septaria" or calcareous mud stones, found in the Oxford clay near Weymouth and elsewhere, consisting of

Carbonate of lime	·60	1·00.
Protoxide of iron	·10	
Silex and alumina	·30	

The stone is broken up and slowly calcined to a **snuff** colour, **not** to the colour of burnt umber, the burning is conducted in kilns, and the result is ground to a fine powder; this must be kept dry and mixed for use with not less than an equal portion of clean sharp river sand, add clear water till it is made into a stiff paste, but no more water than suffices for this purpose.

79. It will take 15 minutes before the **Roman cement**

thus prepared begins to **set**, and it may even take 45 minutes. When it begins to **set**, all the moisture on the surface disappears, the cement feels dry and warm to the touch, and hardens; the hardening continues for months and can be increased by frequently wetting the cement with water in the interim.

80. Roman cement is impervious to water, and hence is used much for lining cisterns and water tanks.

81. When **hydraulic cements** are artificially made with puzzolana or soorki it is impossible to **beat** and **incorporate** the ingredients too much (a point to attend to). Smeaton allowed a bushel of terras morter beaten up as a day's work for one man.

82. All **limes** fit for **hydraulic** cements require to be ground to **powder,** as they **slake** so very reluctantly. The **finer** they are ground so much are they perceptibly and really the better.

83. It is especially important with such **morter** that **no more** be **mixed** at one time than can be **used** within a few **hours.** The best way is to spread the Roman or other cement in powder, and only wet it as it is used up; otherwise they are apt to save themselves trouble by wetting it all at once, and consequently having to use it when partially set.

84. Captain H. Y. D. Scott, of the Royal Engineers, invented a most valuable **cement** at Chatham; the limestone is burnt to quicklime in the usual way, the quicklime is then spread 2′ deep over the perforated arches of an oven and heated to a dull glow; the fire is next raked out, every orifice closed, and pots containing common stick sulphur pushed in on the fire bars; the ignition of these causes a distribution of the sulphurous fumes; the allowance is 15 lbs. sulphur to 1 cubic yard of quicklime: when all is absorbed the oven may be opened, and the cement when cooled is taken out, ground,

and sifted through a fine sieve of 30 meshes to the inch; it is spread on a floor for one day, before packing: if the limestone be pure or feebly hydraulic, one part of **puzzolana** or more, must be added to two parts of the cement; if used for plaster one part of ground chalk is mixed with one part of the cement. The burning takes about 4 hours, and the whole process can be completed in one day.

85. In **plastering** chimneys or walls exposed to great heat, the admixture of cowdung prevents it from cracking and peeling off with the heat.

86. Asphalt makes an excellent **floor** where safe from **fire.** 83 parts powdered **chalk** or limestone to 17 of **tar** are good proportions to mix and boil together, or,

Pitch	18 parts	Asphalt.
Resin	18 „	
Sand	60 „	
Gravel	30 „	
Slack (slaked) lime ..	6 „	

This mixture may be laid on **two inches** thick, for ordinary **floors.**

87. A totally impervious **cement** may be made by melting 120 lbs. pure resin, and adding sand 300 lbs., well stirred in and incorporated. Before the composition hardens in its place, matting should be laid on it or **sand** sprinkled over it to prevent abrasion; this cement is **dangerous** near **fire.**

88. To fill up **cracks** in cement where there is **leakage**, take

Linseed oil	2 seers
Resin	2 „
Pumice stone	1 seer

boil the oil, pound and mix the resin, and last the pounded stone: the mixture is to be just poured into the cracks and smoothed over with a trowel.

CHAPTER VII.

FOUNDATIONS.

1. Ordinary foundations consist of an **excavation** with a **structure** at the bottom of it: the structure may be concrete, beton, sand, brick jelly, masonry, or brickwork; and the superstructure which rests upon it is less wide than the foundation, the width being diminished in footings, &c., generally by offsets of 3″ on each side.

2. The **depth proper** for foundations varies widely, say from 3″ to 6′, the limits being determined by the local features, such as the nature of the soil, depth to which frost penetrates, &c.—say 4′ deep in Britain.

3. If the soil be **rock** it should be cleared of all loose or rotten fragments, and cut into **steps nearly** horizontal, but slightly **turned up** at the outer edges, previous to building upon it.

4. Firm soil includes gravel and hard clay; sand is by no means bad if protected from water. In **firm** soil the only need for **any** depth of foundation is to avoid the disintegrating and disturbing influences of frost and drought, for which purpose from 3′ to 5′ is sufficient depth.

5. No part of any **foundation** should be in **tension**; surface water should always be diverted by catchwater drains; moreover, in **important** works the very foundations themselves should be drained down the middle by a trench filled in with loose stones. The most important consideration for the **durability** of any structure whatever is the draining.

6. The **spread** of the **footings**, or foundation courses of the masonry should be at bottom $1\frac{1}{2}$ time the thickness of the superstructure in a gravel soil, and $2 \times$ thickness in sand or clay soil. (No. 1.)

7. In a soft soil **draining** is even more important than a **wide-spread** foundation.

8. **Concrete** or **beton**, if used for foundations, should be **thrown** from a stage not less than 10′ high, or laid in layers 9″ thick and beaten down to 6″. **Sand** may be merely levelled and built upon; **concrete** should be built upon as soon as ever it is set.

9. Where there is very great weight, and numerous doors, arches, or other openings occur, **inverted arches** may be turned under them; but these inverts, to be of real use, require **extreme** accuracy of construction.

10. The weight of a **submerged structure** is 62·4 lbs. per cubic foot less than its weight in air.

11. Foundations in **soft and wet** ground, if **constantly wet**, may be upon **timber platforms** which are made of beams of oak or elm 12″ square and 3′ apart horizontally, with others laid precisely similar across them at right angles, and halved together at the junctions so as to form 3′ squares, which are filled in with concrete. A layer of 4″ planks overlies the whole, on which the building rests.

12. Instead of timber **iron platforms** may be used. These consist of trough-shaped girders with vertical sides, laid on their backs, bolted together, and filled with concrete.

13. **Ground** may be **consolidated** by driving short piles 6′ to 12′ long and 6″ to 9″ diameter as close together as can be done without starting their neighbours; on these piles may be built a **platform**, a layer of **concrete**, or **both**.

14. **Bearing piles** are such as act like pillars, each

supporting its proportionate share of the total weight of the superincumbent building.

15. Piles may be **driven** till they reach a firm stratum, or till the friction holds them from sinking $\frac{1}{8}$ of an inch under 30 five-foot blows of an 800-lb. **ram.**

16. Piles may be **loaded** up to 1000 lbs. per square inch of head area, if resting on firm ground, or 200 lbs. per ditto if merely held by friction. The **diameters** of piles range from 9″ to 18″; they are made of elm, straight-grained, barked, and smoothed.

17. The **diameter** of a pile should never be less than $\frac{1}{20}$ of its length; they are usually driven at horizontal distances of 3′ apart from centre to centre. They should be driven with the natural **butt end** of the tree downwards; this is sharpened to a point whose length is $1\frac{1}{2}$ time the diameter, and shod with cast or wrought iron spiked on if the soil is stony. The **head** of a pile is bound with a wrought-iron **hoop** to keep it from splitting under the blows.

18. The **ram** of a pile-driving machine may be worked by a rope over a pulley: this is called a **ringing engine**; each man holds an end of rope, pulls a strength of 40 lbs. or so, lifting the ram 3′ or 4′, and lets go. The men rest every 3 or 4 minutes; this gives about 5000 blows per day.

19. The **monkey engine** has a ram 400 lbs. weight, which is drawn 10′ or 15′ up to the top of a frame made as a triangular pyramid, by a capstan and windlass driven by men, horses, or steam power.

20. Air pressure **engines** for lifting the ram, or **steam hammers** for driving the piles, may be used; the piles may be driven **raking**, or perpendicular, according to the direction of the thrust upon them; when the pile sinks low a punch or **dolly** may be **interposed** to transmit the blows.

21. Piles may be **drawn** by hydraulic pressure.

22. When the upper stratum is so **soft** that the **lateral stability** of piles is doubtful, **stones** may be thrown in round them.

23. When the **piles** are **driven home**, their heads are sawn off level to receive the **platform** (Nos. 15 and 11), consisting of a **grating** of elm beams 12″ × 12″ in section (as in No. 11), called **string** pieces and **cross** pieces, halved into each other's depth where they cross, and spiked down at those points to the heads of the piles by trenails. (V., 57.)

24. The **soft ground** about the heads of the **piles** is to be **scooped out**, and in the intervals hydraulic concrete is to be filled in and rammed in layers not more than 12″ thick. The interstices also of the timber platform are to be filled with hydraulic concrete; over the whole 4″ elm planking is nailed. The **outermost** beams all round are generally made so deep that their upper sides are **flush** with that of the planking, these beams are then called the "**capping**," and the planks are sunk into a recess cut in their edges, like a **rebate joint** of carpentry.

25. **Piles** may be driven into **rock** by first jumping holes in it rather smaller than the end of the pile.

26. The best shape for a **cast-iron pile** is a **tube** which is driven by a ram also, but with a timber punch interposed.

27. **Screw piles** were invented by Alexander Mitchell; they should be **cylindrical**, or if polygonal not less than an octagon. There is a screw at the lower end made of cast iron, whose diameter is from 2 to 8 times the diameter of the shaft, its pitch is from $\frac{1}{2}$ to $\frac{1}{4}$ of its diameter and makes only one turn. They are driven by men or horses working at radiating levers on a temporary platform; say four 40′-levers with 8 bullocks yoked to each. The screw may be 4′ 6″ diameter for ordinary soil.

28. Screw piles may be driven from 20′ to 45′ as an average, then the **pressure** is from 14 lbs. to 31 lbs. per square inch, the angle of repose ϕ for fixed earth being taken at 19° to 28°. The greatest safe working stress, without fear of wrenching, is 4000 lbs. per square inch.

29. Sheet piles are flat piles driven successively edge to edge; their use is to keep material from spreading or undermining; they may be made of either timber or iron.

30. Timber sheet piles are planks of any procurable breadth, $2\frac{1}{2}''$ to 10″ thick, sharpened to an edge at the base, and shod or not with **sheet iron**; the sides are feathered and grooved to fit each other tight.

31. The **process of driving** sheet piles is as follows: First, guide piles, the usual size, say 9″ to 18″ diameter, are driven at intervals of 6′ to 10′ all round the ground which is to be enclosed by the sheet piling; on to these guide piles horizontal string-pieces or **wales** are notched in pairs opposite each other, the notch is cut so deep that when the pair of wales are fixed parallel and opposite to each other, there will be just space sufficient throughout their length for the tops of the sheet piles to intervene **flatways** between them, then the **wales** are bolted together through the guide piles. If the sheet piles are to stand more than 10′ out of the ground, a second row of pairs of wales must be notched and bolted on near the ground as above.

32. The **sheet piles** are **driven** to about half the **depth** of the guide piles, commencing from the near sides of two adjacent guide piles, and working inwards till they nearly meet, when the last sheet pile is driven as a **wedge** to tighten the rest.

33. If **sheet piling** is to be of **iron**, the best kind is channel iron, this shape answers for both guides and sheets; tubular iron may also be used. The piles are

driven with the backs outwards, flanges inwards, and so bolted together. The edges are formed to overlap joint outside.

34. For the **foundations** of Chelsea Bridge, the following **dimensions** wère used: **Guide piles**, tubular, flat outside, semi-cylindrical inside of the enclosure, 1″ thick, 12″ external diameter, 27′ long. **Sheet piles** were cast-iron plates, 10′ long × 7′ broad × 1″ thick, with vertical ribs 4″ to 6″ deep, and 10″ to 1′ 8″ apart, one horizontal rib of the same size on the upper edge.

35. Timber or iron **cased concrete foundations.** In these the sheet piling is constructed first as above, then the material is scooped out, the casing braced transversely to resist pressure from within as well as from without, and strong hydraulic concrete (beton) is shot in layers not more than 12″ thick, time being given for it to **set** or become firm before proceeding, for a heavy load retards the setting. **Bearing piles** (No. 14) may be combined with a cased concrete foundation as above.

36. Iron tubular foundations consist of large, hollow, vertical, cast-iron cylinders, filled with rubble masonry (IX., 48) or concrete (VI., 15), the earth having been previously scooped and bucketed out. The process is similar to that of sinking **pot wells** in the Madras Presidency. The diameter of such a cast-iron cylinder may be 10′ and the length 70′; 6 to 8 men can work inside at once, and the length may be in 9′ joints with top and bottom flanges bolted together.

37. Between the joints a **water-proof cement** may be interposed, consisting of—

Iron turnings	1000 lbs.
Sal ammoniac	10 „
Flowers of sulphur	2 „
And, to dissolve the sal ammoniac, water	Quantum suff.

38. Instead of water-proof cement, a **ring-shaped** cord of **vulcanized india-rubber**, enclosed in grooves at the joints, may be used to render them water-tight.

39. The **bottom** length has a sharp **edge** at its lower end, to assist in sinking it into the ground.

40. A **caisson** is a flat-bottomed **boat**, of which the **sides** can be **disconnected** from the bottom; it is loaded with the foundation courses of the intended structure, floated out to the site of the work (where piles have been previously driven, concrete laid, &c.), and it is there sunk gradually by slowly admitting the water; the sides are then detached and removed; the bottom, whose dimensions and figure should be suited to form part of a permanent foundation, being made of **elm**, is left embedded permanently in the structure.

41. The **bottom** of a **caisson** is supported on transverse elm beams 10″ × 10″ section, and 3′ apart from centre to centre; these project beyond the sides of the caisson, their ends have an **eye** screwed into them on the upper side; a vertical iron bolt hooks into this eye and connects it with a similar parallel and opposite beam of the same dimensions lying transversely across the caisson **above**. The bottom can be easily disconnected by unhooking the iron rods below.

42. Common **dimensions** for a **caisson** are 63′ × 21′ × 15′ deep; the masonry within, 18′ broad; cross beams 10″ × 10″ at a distance of 2′ 10″ apart; upright standards of the sides 10″ × 10″ at a distance of 5′ 8″ apart from centre to centre.

43. The **seat** may be prepared for a **caisson** foundation by **excavation** alone if concrete is unnecessary.

44. **Caissons** have been made of **bricks** and **cement** in a graving dock, coated with coal tar, floated out into position, filled with concrete, and thus sunk.

45. Where the **bed** is clay, it may be sufficient to

sink the foundations, even for **piers** of bridges, a few feet into it, merely **spreading** them out in steps by offsets. (No. 1.)

46. Sand is by no means bad for **foundations**, if protected from current and well drained, otherwise it becomes quicksand.

47. Never trust to **hearsay** or conjecture about **borings**.

48. Where the bed is **sand**, the foundations may be on **boxes, pot wells**, or **blocks**.

49. A **box foundation** is simply a large box of timber without top or bottom, large enough to enclose the pier and 9″ more in each dimension, from 6′ to 10′ deep: the ground is first measured and pegged out with string, the box is placed in position, men get inside, scoop out the sand, and throw it over the sides; thus the box sinks, and is then filled with rubble masonry.

50. All **belts** or **fastenings across** the sides of boxes, or any other structures to be sunk whole, must be **inside**, never outside.

51. Beyond a **depth of 12′**, **boxes** become inapplicable, and **pot wells** or **blocks** should be adopted.

52. Pot wells consist of a series of cylinders or **rings** burnt entire; they are made of clay, and each has a lower flange to fit into the ring below it; **pot wells** are generally 6′ diameter, and 6′ to 10′ is found sufficient depth; they are sunk in precisely the same manner as **boxes** are (No. 49), but it is more difficult to keep them truly vertical while sinking; when sunk to the requisite depth they are filled with **brick jelli**, or concrete; they should **never** be more than 40′ deep. (VI., 49.)

53. Block foundations are **masses** of masonry, **pierced** with wells 3′ to 5′ diameter and not more than

3′ apart; **blocks** are more stable than **wells**, and altogether handier to construct.

54. In India **sand** has been **scooped out** by a flood to a depth of 23 feet. See (IV., 236).

54a. Oblique sheet piling might divert a good deal of the scour. (No. 58.)

55. In **driving piles** a heavy ram with a short drop is preferable to a light weight with a long drop to generate the required momentum; the quicker the blows are given the better; a pile half driven and left becomes soon immovable from friction.

56. Inverts may be turned under arches, but they are only applicable when **safe** from **undermining** action of the water: they are suitable for a weak clay soil if protected by **curtain walls** a few feet deep, or piling, or both.

57. A **flooring** of masonry should have curtain walls or rows of sheet piling under the edges.

58. Where **piles** are used to support an **oblique** thrust they should be driven in the line of thrust. Such a manner of driving piles is difficult without a special machine for the purpose.

59. The great desideratum for **foundations** is that the soil should be **uniform**; even "made ground" is safe, provided it be uniformly yielding: the great and only cause of failure is **inequality** of settlement. (III., 177.)

60. In **bad** soil, **platforms**, or **inverts**, or **both**, may be placed under culverts, &c. Such platforms might be 1′ thick, made of concrete. (No. 56.)

61. In pure sand with a slope of 3′ 6″ per mile, acted on by a flood 12′ to 15′ deep, **pot wells** 6′ deep, as foundations, in front and rear of a dam, have been proved to be **safe**.

62. For foundations of **embankments**, especially in bogs (see III., 182), piles, sand piles, and sand flooring

may be used if drainage fails; on the other hand, hurdles, fascines, and brushwood are **not** admissible in such situations.

63. In all cases the nature of the **subsoil** is the most important point to determine, and for this purpose a pit should be dug: where the soil is various and the structure precarious, many borings must be made.

64. Solid **rock**, compact **stony soils**, **hard clay**, require no preparation beyond sinking and levelling for foundations.

65. Pure **gravel** or **sand** requires lateral confinement; if the lateral soil is insufficient, sheet piling or masonry walls must **confine** the bed, which should also be drained. If **water** is found in any quantity and pumps or scoops fail to keep it under, a row of sheet piling must be driven on each side of the foundation, below the bottom of the bed, the **exterior** excavated and rammed with clay puddle; if this too is insufficient, the foundation must be laid in **small portions** at a time, excavated and immediately built up, béton being highly suitable.

66. All varieties of **compressible soil**, including ordinary clay, common earths, marshy soils, and generally all which do **not** require the pickaxe to loosen them, do require peculiar caution in laying foundations.

67. In the better classes of **compressible soils** it is generally sufficient to dig a trench 3′ deep and ram 12″ layers of béton or concrete in it, taking care that where **offsets** occur in the thickness, the béton is properly confined by boarding till it **sets.**

68. When **water** interrupts such a foundation and **cannot** be **drained** away by trenches filled with loose blocks of stone, the **beton** may be cased in **tarred canvas**, or sandbags, to give it time for setting.

69. Piling is the best remedy, combined with draining if possible, for **marshy ground**: if timber piling

be inadmissible on account of white ants, and iron on account of expense, **curtain walls** may surround the bed and a platform of béton cover it; these are all the better for the insertion of iron **bond.**

70. Otherwise in **marshy ground**, a deep trench may be dug all round, and the ground interior to it **raised** so as to constitute a platform of "made ground" **well drained; piles, sand piles**, or masonry **pillars** may pierce the whole area; say, if timber piles, 6′ to 12′ long and 6″ to 9″ diameter; if **sand piles,** 12″ diameter and 6′ long; if masonry pillars, 12″ × 12″ × 6′ long, and in any case 2′ 6″ **apart** in each direction from centre to centre: this being about the closest interval at which 12″ piles can be driven without starting their neighbours. The intervals around the tops of these supports may be rammed with béton or clay puddle, or a timber platform may be laid on it as in (No. 24).

71. Pot wells are properly suitable to **pure sand**, or to **compressible** soil of any nature when a good bed underlies it at a reasonable depth; where the depth is beyond 40′, piles or block foundation should be adopted in such soil.

72. Wooden piles do not answer in India, owing to white ants, and to the condition of alternate wet and dryness, which rapidly decays them. Iron screw piles are generally preferable for works in India, or else **pot wells.**

73. Pot wells have the advantage over **blocks** in not requiring skilled labour, but blocks are more stable; both are constructed upon "*Nimchaks*," or curbs of timber 6″ to 18″ deep, of hard wood, or iron, upon which the masonry or well rings are laid 4′ deep, when the sand is scooped out from the interior and the mass is sunk 4′, again built up and sunk successively in 4′ stages. The **jham** or iron sharp-edged bucket is used

to scoop out the soil, and great caution is necessary to excavate **evenly** all over, else the **curb** will break and the masonry fall in: hand scooping is used for the first 5′ of depth.

74. The **sand pump** consists essentially of a cast-iron cylinder 3′ in diameter and 2′ high, with a pump fixed on its air-tight cover, valves opening upwards. The pump is worked by tackle from above when lowered, so as to suck out the air and suck in the sand into the cylinder's bottom. There are blades of $\frac{1}{2}''$ plate iron fixed as radiating cutters below the suction pipe; they are steeled and sharpened, so that by raising the body 4′ or so and jumping it on obstacles they can be cut up and removed in detail. By the **sand pump,** masonry wells 12′ 6″ in diameter have been sunk 3′ to 7′ in one day.

75. In order to prevent the **shells** of very long masonry wells from **parting company,** they may be built on iron plate curbs, punched for long iron tie rods, extending upwards through the well rings at 5′ lateral intervals apart; on to these rods a ring of flat iron may be dropped at every 5′ and pinned down through the rod.

76. Piers for heavy railway bridges have been constructed on **artificial islands,** formed by throwing in sandbags and loose sand. The space covered at base was set out as $175' \times 120'$; this was heaped till an island stood out through 15′ of water, and continued till the surface was $100' \times 60'$. On this island ten iron **curbs** were laid about 15′ apart from centre to centre. The curbs were 8′ 6″ interior and 13′ 6″ exterior diameter of $\frac{3}{8}$ inch boiler plate, 2′ 6″ wide, riveted to an external ring 18″ deep of similar plate extending 3″ above it as a hold to the superincumbent brickwork whose inside was corbelled inwards to form a thickness of 3′ $4\frac{1}{2}''$.

The curb was let into the ground and 12′ of brickwork built above it, and sunk to the water level at its upper edge, then 15′ more were built and sunk; and lastly, an additional 16′, making 43′ in all.

77. The next step was to clear out the rubbish and level the bottom for the **concrete** or **beton**, composed of 1 part of fresh-burnt unslaked lime, 1 of broken bricks, 2 of underburnt lime; this took 18 days to set, en masse: above the concrete, a disk made of two thicknesses of 2″ planking, covered by 3′ deep of brickwork, was let down and firmly wedged all round the edges with wood; above this again the water was baled out and rubble masonry built up to the top of the wells.

78. The wells were covered by **large flat stones** let into grooves cut in the tops of the cylinders; the stones were cramped with 1¼ inch square iron, and the upper course stones were dropped into joggles cut in those below. **Concrete** was thrown in between the cylinders, and both the inside and outside of the cylinders corbelled in 2½ inch offsets to cover the spaces left.

79. The **rate** of sinking such wells or cylinders varied from 15″ at top to 4½″ at 20′ deep, and 1″ per day at 40′ deep.

80. The **piers** of the **Solani aqueduct** rest on foundations consisting of eight **blocks** of brickwork, each block measuring 22′ × 20′ × 20′ deep, and containing 4 wells 6′ 6″ × 5′ 6″ or so, with 3′ thickness of brickwork around and between them; the brickwork is well bonded with 5 strips of hoop iron in each layer, the layers are 12″ vertically apart, lengthways and crossways alternately: the masonry is on **curb frames** 12″ square, **halved** into each other, not notched together. All projections or irregularities on the **outside** of such casing must be avoided. (No. 50.)

81. In sinking **blocks** trifling divergences from the perpendicular are easily rectified by the scoop, if the block is broad and well shaped; a **taper** given to an ill-shaped **block** improves its adjustability into position.

82. Where **boulders** of **stone** or slate are likely to be met with in sand, a coffer-dam is preferable to wells or block foundations.

83. When the **depth** of **water** is **great**, or leakage in sand irrepressible, a caisson is preferable to a coffer-dam; but a good bed should be laid to hold the caisson, whose sides and bottom may be of pacca masonry, well braced and lined with tarred canvas; it may be floated out, and sunk on a timber flooring into its bed, where it can be subsequently filled in with masonry or concrete. (See No. 44.)

84. **Driving piles** whose heads are afterwards sawn off level, laying a bed of **concrete**, or merely **levelling** the bottom, are the usual means of preparing a **bed** for the **caisson**, which is then moored over the place, and gradually sunk into position.

85. Where the foundation is to **cover a large** surface caissons will not answer, and an artificial island must be made by throwing in blocks of stone, or sand-bags and sand, till they assume their natural slope, and rise out of the water say 3′, when wells may be sunk if in sand, or foundation proper commenced if the island be of stone. (No. 76.)

86. In **running** water the soil around the bed must be **protected** by dry blocks of stone thrown in, else the foundation will be liable to gradual undermining: this will be sufficient, **unless** the soil be **sand** or **gravel**, in which case the bottom around the bed must be scooped out from 3′ to 6′ deep, and filled with béton.

87. The **engine** for **driving** piles may be either a crab engine or a ringing engine, according to the

means used for hoisting the cast-iron monkey. The wheel at the top is of cast iron, 1′ 1″ diameter, and fluted on its edge to receive the rope. The usual weight of ram is 500 lbs. to 780 lbs. The piles usually run from mere posts, to piles 9″ diameter for light work, and from 9″ to 18″ for heavy foundations; those for the Nottar viaduct at St. Germains are 22″ square, made of lengths breaking joint, shod and bound together; the monkey or ram weighed 4 tons, with a fall of from 2′ to 4′ 6″.

88. If the **foundation** of **any** structure be not **uniform** it will pull itself to pieces by inequality of settlement; this is a point of great importance.

89. Where **piles** are to be driven into ground covered with water, the pile-driving **engine** may be **floated** out and **moored.** The engine employed at the **Nottar** bridge, St. Germains, required a 50′ square raft to float it out, the monkey weighed 4 tons, the fall varied from 2′ to 4′ 6″, the engine was 42 feet high; the piles were 22″ square, made of four timbers bound and shod together: the monkey required nine 13″ square masts to float it out.

90. In order to ascertain if the **ground is firm** under a foundation **trench** a heavy wooden beetle is used, and the ground if hollow will indicate the fact on being struck; water is poured in for the same purpose.

91. No **excavation** should be allowed **near** a foundation trench.

92. Foundations of **colonnades.** (See IX., 97.)

93. For **keeping** foundations **clear of water** within **coffer-dams,** baling is rarely sufficient or convenient; the most efficient method where the leakage is not excessive, is to dig a hole 18″ × 18″ at the lowest spot to which the influent water naturally runs, and there insert the end of a suction pump; which pump may be

of any description, from the engine-driven centrifugal pump, to the roughest possible contrivance improvised by boring a hole down a post, or series of posts, with one end sharpened and so let into the hole at the butt end of the next; in this hole a plunger is worked from a rod attached to a cross piece driven by two men, who are constantly relieved, and thus keep the pump in continual activity.

CHAPTER VIII.

IRONWORK, METALS, AND ENGINES.

1.

Bronze is made of	**90**	**parts**	**copper to**	**10**	**of tin.**
Bell metal,	**189**	,,	,,	**59**	,,
Hard-bronze,	**441**	,,	,,	**59**	,,
Gun metal,	**504**	,,	,,	**59**	,,
Soft bronze,	**567**	,,	,,	**59**	,,

The tenacity of soft bronze is equal to that of cast iron.

2.

Brass is made of or Hardened copper.	**189**	**parts**	**copper to**	**32·5**	**zinc.**
Malleable brass,	**126**	,,	,,	**32·5**	,,
Ordinary brass,	**63**	,,	,,	**32·5**	,,
Very hard brass,	**31·5**	,,	,,	**32·5**	,,

3. **Aluminium bronze** is made of from 5 to 10 of aluminium with 95 to 90 of copper.

4. **Copper** is hard and durable, but costs six or eight times as much as iron. **Verdigris is a carbonate** of copper, not an **oxide.**

5. **Lead** is used for coverings and for fastenings in masonry, as well as between the voussoirs of arches.

6. **Tin** melts at 426° Fahrenheit, and **combines** with iron to form **tin-plate**; tin forms alloys when melted with other metals: thus **pewter** = 8 tin to 20 lead.

7. **Zinc** is used for covering roofs and for **galvanizing** iron. Galvanized iron is slightly less tenacious than the plain iron. Zinc burns at 700°.

8. **Iron ores** are chiefly the oxides and carbonate; **hæmatite** is red oxide of iron, or specular iron; yellow ochre is a brown ore.

9. To prepare **iron** from the **ore**, if a **carbonate** the carbonic acid is expelled by heat, leaving **oxide of iron**, from which earthy constituents are removed by **lime**, lime having a greater affinity for such; this leaves a glassy refuse called **slag**. From the oxide of iron the oxygen is extracted by carbon.

10. Lime is used as a **flux**, to facilitate fusion.

11. In **smelting**, the ore is broken up into fragments, mixed with fuel and flux, and melted in a blast furnace. The proportions of ore, fuel, and flux can only be determined by trial.

11a. Slag and **pig iron** are the products of the smelting process. Pig iron contains from 2 to 5 per cent. of **carbon** with the **iron**, and possibly a little uncombined carbon as **plumbago.**

12. Cast iron is the result of **smelting**; it is iron and carbon. **Malleable cast iron** is made by subtracting carbon from the cast iron by heating to a bright red heat, embedded in **hæmatite** (No. 8), which requires 24 hours; maintaining the heat 3 to 5 days, and cooling for 24 hours.

13. Red short iron is that which is rendered brittle at high temperatures by the presence of **sulphur** or **magnesium.**

14. Cold short iron is that which is rendered brittle at low temperatures by the presence of phosphorus or silicon. **Sulphur** generally comes from the **fuel**; **phosphorus** from the **ore**; hence charcoal is the best fuel.

15. If **either calcium or silicon** be present in the ore, the **other** must be used as flux to form slag. (No. 11.)

16. Grey cast iron is the softer and more fusible; it is made at a higher temperature.

17. White cast iron is silvery white, brittle, hard,

more difficult to melt, and is produced by deficiency of fuel: it is **inadmissible** in engineering from its brittleness, except only in the process of **chilling** iron: the white and grey cast iron are convertible subsequently by fusion and cooling.

18. Numbers **2 and 3,** as they are called, of cast iron, are usually the best, combining strength and pliability.

19. The average of **hot-blast iron** is **not** better than cold blast.

20. Chilling iron consists in placing pieces of cold iron in the mould, where hardness in the casting is wanted, and then running in the metal; when it comes in contact with the cold iron it becomes suddenly converted into white granular iron at the surface.

21. Toughened cast iron is made by adding $\frac{1}{4}$ to $\frac{1}{7}$ of wrought-iron scrap to the molten metal. Solid iron will float on melted iron.

22. The **oftener** iron is melted the **harder** it becomes; and the oftener it is melted, up to the **twelfth** time, the **stronger** it becomes.

23. Changes of temperature, or **intense** cold, render iron brittle and apt to split.

24. The **proof strength** of cast iron is one-third of the **breaking load,** and the proper or **working** load is $\frac{1}{6}$ of the breaking load.

25. For large castings Fairbairn recommended the following admixture of various kinds of iron :—

Lowmoor iron, No. 3	30 %
Blaina iron, No. 2	25 „
Derbyshire iron, No. 3	25 „
Good old malleable scrap iron ..	20 „
	100

26. The **texture** of iron should be fine and close,

never mottled; it should be soft enough to **show** the blow of a hammer on its edge.

27. **Air bubbles** are tested for by ringing the iron with a hammer.

28. **Melted iron contracts** one-eighth part of an inch to the foot in cooling, this shrinkage must be allowed for in the moulds for the casting; castings of any **length** must be made with the length vertical, that is **on end,** not lying flat, and the melted iron should be run in from the bottom to avoid air bubbles. A **dead head** should be left at the top, for this cools first, is lightest, and forces down the more liquid metal into the recesses of the mould.

29. Iron ore is frequently roasted or calcined before smelting, in order to expel carbonic acid and water.

30. **Cast** iron is simply iron and carbon, **malleable** or **wrought** iron is simply pure iron. The manufacture of **steel** from cast iron is therefore the most general and inexpensive; that from wrought iron is the more perfect.

31. **Wrought** or malleable **iron** may be made **direct** from the ore, or from cast iron: the process of **direct** reduction is only applicable to pure rich ores; it leaves a slag or cinder which contains oxide of iron and yields pig iron by smelting.

32. The most usual **process** is from **forge pig,** a white pig iron which is unfit for castings; the operation is very various, but generally it consists of melting pig iron in close contact with silicon or lime (No. 15), and a current of air. The carbon is oxidated by the current of air and escapes as carbonic acid gas; while the silicon forms **slag** with the lime, whichever is introduced as a flux.

33. **Chloride of sodium** (common salt) is used to remove sulphur and phosphorus. (Nos. 13, 14.)

34. **Puddling** means melting pig iron in a rever-

beratory furnace and raking it into close contact with the air by a **rabble,** this gets rid of the carbon (No. 32), and forms it into malleable iron.

35. **Pig boiling** is when the pig is puddled without **refining.**

36. **Refiner's metal** is made by having a blast of air blown over the surface of pig iron in a melted state, this removes part of the carbon and leaves refiner's metal, which is **thicker** without the carbon.

37. **Loup** or **bloom** means the lump of thickened pig iron which is taken out and put under a tilt hammer to be **shingled,** that is to have the cinder forced out, and the particles **welded.**

38. The **bloom** is then rolled into a bar, cut into short lengths, fagoted together, reheated and rerolled into one bar, and the same process repeated ad libitum.

39. In **Bessemer's process** the molten pig has air blown through it; it is then run into ingots, hammered and rolled. The iron for Bessemer's process must be free from sulphur or phosphorus.

40. **Welding** is performed by raising two pieces of malleable iron nearly to a white heat, and hammering them; it is essential that the contiguous surfaces be clean, free from oxide or cinder, and in close contact.

41. **Plate iron** has alternate layers of fibres crossing each other.

42. **Rails** are **rolled** out of fagots; and if the fagots (38) were badly piled, the rails will show seams.

Smith's iron is wrought or malleable iron.

43. **Steel** is a compound of iron with from 0·5 to 1·5 per cent. of its weight of **carbon:** the **more** carbon, the **stronger** and more easily fusible but the **less tough** will it be; the **less** carbon, the more easily welded and forged.

44. **Silicon** (quartz, sand, or flint) in the propor-

tion of $\frac{1}{2000}$ part by weight, stops the too violent ebullition of steel, more would make it brittle.

45. **Manganese** makes steel tougher and easier to weld or forge.

46. **Tempering steel** means cooling it suddenly, which renders it very hard; if wanted soft it is **afterwards reheated** and cooled gradually; the steel is reheated by plunging it into a bath of fusible metallic alloy; the gradual cooling process is called **annealing.** Re-entering angles should never be allowed, all changes of thickness should be gradual and curved.

47. **Steel** can be made by **abstracting** carbon from cast iron, or by adding carbon to malleable iron. (See No. 30.)

48. The **strength** of **steel** is greatly increased by hardening in **oil.**

49. The purest **wrought iron** is manufactured by charcoal from **magnetic iron ore.**

50. **Homogeneous metal** is steel, cast from bars of the purest wrought iron, with manganese (No. 45) and carbon enough to form steel (No. 43).

51. **Blister steel** is made by embedding bars of the purest wrought iron in charcoal and highly heating; this process is called **cementing,** and if applied **only to the surface** of wrought iron it is called **case-hardening**; thus scissors and other such articles are made of wrought iron with a **steel skin** formed by heating them in charcoal.

52. **Shear steel** is rolled out of bars of blister steel in fagots at a welding heat, the process being repeated (as in No. 38); it is used for working tools.

53. **Cast steel** is blister steel remelted in a crucible with **coal tar** (carbon) and manganese; it is **far the best steel.**

54. **Air-blast steel** is made either by stopping the

jets of air (No. 39) when enough carbon has been abstracted from the pig, or by abstracting the whole of the carbon by oxidation and subsequently adding the necessary carbon with manganese and silicon. (44, 45.)

55. **Puddled steel** is made by stopping the process of puddling pig iron at the right point.

56. **Granulated** steel is made by running melted pig iron into water and dashing it about over a wheel in its course. The lumps are afterwards highly heated with pulverized hæmatite. (No. 8.)

57. In order to **protect** iron, it may be raised to a dull red **heat,** and then **boiled** in coal **tar,** or **smeared** with cold linseed **oil,** or **painted** with oil paint, or **galvanized** with zinc.

58. To **galvanize** iron, clean and immerse it with a plate of **zinc** in a solution of oxide of zinc and potash; apply the negative pole of a battery to the iron and the positive pole to the zinc. Galvanized iron is inadmissible in coal atmosphere or near the sea, owing to the decomposing power of sulphuric and muriatic acid.

59. **Cast iron** does not **rust** easily if its skin be uninjured; the **skin** consists of silicate of protoxide of iron from the sand in the casting mould.

60. The more **traffic** the less **rust** on **rails**: variations of wet and dry, impurities, or contact with electro-negative metal promote **rust.**

61. **Iron pipes** are best preserved by coating with **pitch** both inside and out. (See IV., 101.)

62. **Rivets** are iron fastenings made of the toughest **wrought** iron: they must fit tight into their holes; the **diameter** of a rivet should be from $1\frac{1}{2}$ to 2 times the thickness of the plate, and the length of the rivet should be $2\frac{1}{2}$ times the diameter of the rivet, + thickness of the plates.

63. When the rivets are **clenched** their tenacity is equal to that of good iron plates = say 50,000 lbs. per square inch, the sectional area of the rivet holes should be equal to the sectional area of the plate left unpunched.

64. Pins, keys, and **wedges** must **fit tight. Pins** fit in round **eyes** and answer for ends of **ties. Wedges** act in oval eyeholes called **slots,** they admit of being driven home and so tightened up. The wedge or key should never exceed 4° inclination or taper, from perpendicular to the strain across it, else it will be apt to slip out.

65. Screws and **nuts.** The effective diameter of a screw is that of the **spindle** only, the projection of the thread from the spindle should be $\frac{1}{16}$ of the effective diameter. The **pitch** or inclination of the thread may be $\frac{1}{8}$ of the effective diameter.

66. The most usual forms of **iron bars** are angle iron, T iron, H iron, I iron with or without the two **flanges** on the **web,** channel iron, and bulb iron.

67. Iron ties should always be of **wrought** iron, **struts** of **cast** iron, either round tube or **cross** section.

68. To connect **ties** together lengthways, a chain-riveted fish joint is used. For the ends of ties any of the modes given in (No. 64) may be adopted as fastenings.

69. The **cross** is a very good section for a wrought-iron **girder**; it may be formed either of two T irons placed back to back, or of three straights and four angle irons alone. The diagonal struts of Warren girders may be formed in this manner.

70. The strongest and stiffest form for a **wrought-iron** girder, that is, for a girder whose length exceeds 26 times its diameter, is a cell; for less than 26 times

its diameter, or than 13 times its diameter if hinged, the tube or cross X section of (No. 67) will answer, and should be of **cast iron.**

71. As the **girders** have not much abutting surface in their transverse section, the end must be riveted to other pieces of the framework.

72. Hinges work on cylindrical pins; rolling blocks are used under one end of girders. (No. 85.)

73. The different **pieces** of a built **strut** should have their ends **breaking joint.**

74. The most useful forms for **cast-iron beams** are the T, double T, and channel iron.

75. To lengthen a **cast-iron beam** the joint must be true, clean, plane, and perpendicular to the axis of the beam; the portion above the **neutral axis** must abut truly to meet the compressive strain; the part below the neutral axis is connected by transverse flanges and wrought-iron bolts. The sectional **area of the bolts** must be half that of the cast-iron table for which they do duty.

76. A plain **wrought**-iron beam **gives way** by its top flange bending sideways.

77. Cambering, whether applied to timber or iron structures, means building **convexer** than the intended form, so as to allow for **deflection,** when loaded, into the intended position: thus a wrought-iron beam may be cambered slightly **above** its loaded position.

78. Gussets are corner pieces to rigidly connect the horizontal **tables** with the vertical **webs** of a great tubular girder. (No. 70.)

79. Girders have been made of elliptical hollow **tubes** with the minor axis vertical 13′ deep; span 430′ to 460′, the ties hanging in a catenary curve, the roadway being suspended from the bow formed by the girder; the whole floated out on caissons, lifted 3′ at a time by

hydraulic pressure, and the brickwork built up underneath as the mass was lifted.

80. **Tie rods** are very frequently **cambered** up. (No. 77.)

81. The best forms for **trusses** are the triangular truss, trapezoidal truss, Warren girder, bow-string girder, lattice girder, and braced-iron arches. The former three are sufficiently clear.

82. The **bowstring girder** has the bow of either cast or wrought iron springing from two shoes or sockets connected by a horizontal tie; the cross joists of the platform are suspended from the bow. The proper form for the **curve** is a parabola, but as a circular arc differs insensibly from a parabola up to 60° the circular arc is commonly used. A cylindrical tube is the strongest form, but **channel iron** form is most convenient for suspending rods from. The **suspending pieces** are I-shaped and riveted below to the plate or box beams that form the cross joists; the **main tie** is made of parallel flat bars **on edge**; the **diagonal braces** are round or flat rods.

83. The **lattice girder** consists of an upper and lower horizontal **boom**, shaped and designed to resist thrust and tension respectively, connected throughout by diagonal braces.

84. In **braced-iron arches** each half-arch with its spandril forms one frame or truss.

85. In order to allow for expansion and contraction of so large a mass as an iron bridge, only **one end** should be fixed, the other being supported on **rolling blocks.**

86. **Iron piers** may consist of any number, say from 1 to 14 hollow cylindrical cast-iron pillars, vertical, or for a strong current driven raking, with struts inclined at 30°. The pillars are in lengths of from 9′ to 17′; external

diameter, from 12″ to 2′ 6″, or even 10′; thickness, from $\frac{3}{8}''$ to $\frac{7}{8}''$, or even 2″.

87. Such **iron piers** have been constructed 200′ high, tapering from 60′ × 27′ at the foot to 30′ × 18′ at the top. The horizontal braces are cast-iron I-shaped beams 12″ deep, flanges 5″ broad. The diagonal braces in the vertical and tapering planes are flat bars 4″ × $\frac{3}{4}''$. Each column has a base spreading to 3′ × 3′ from its lower end, 4′ high, and resting on a masonry foundation, to which it is bolted and joggled; the horizontal diagonal rods are 2″ diameter.

88. The **cast-iron piers** may consist of three hollow cylindrical vertical cast-iron pillars, the **flanges** below ground for the lengths buried are **internal** (No. 86, VII., 50), those for the lengths above ground are external; 2′ 6″ is the least external diameter which with a thickness of 1″ will allow a workman room to get inside and fasten the rivets; each flange has 10 bolts, the pillars are 14′ from centre to centre; the braces T iron, 6 square inches sectional area; and diagonal braces, angle iron 4 square inches transverse sectional area. The lowest length (No. 86) forms a screw pile whose screw is 4′ 6″ diameter, by which the pillar is screwed from 20′ to 45′ deep into the earth. If rock is met, a hole 2′ deep is made and the pillar fixed in it by cement.

89. **Anchoring** chains are used for **suspension bridges,** oblique chains and guy ropes to check oscillation; the chains are anchored right back into the abutments.

90. **Auxiliary girders** are straight girders suspended from the chain; they may be plate, zigzag (Warren), or lattice girders, and the ends should be not merely supported but **fastened down.** The girder should be hinged in the middle, by making it in two halves connected by a cylindrical pin.

91. For timber **fish plates, bolts,** &c., see (V., 57) and (V., 40 to 44).

92. For **stone cramps,** &c., see (IX., 54).

93. The **neutral axis** (No. 75) in a rectangular cast-iron beam is at a depth of $\frac{1}{8}$ from its upper edge, or $\frac{7}{8}$ above its lower edge.

94. For bridges up to 40′ span, **cast-iron girders** are cheap and good, larger castings are untrustworthy, but several smaller castings may be bolted together.

95. Cast iron bears	45	tons crushing per square inch.
Wrought iron,	12	,, ,,
Cast iron,	5	tons tension per square inch.
Wrought iron,	17	,, ,,

Hence **cast iron** is far the best for struts and columns; **wrought iron** is the best for ties.

96. Bar iron varies from	$\frac{5}{8}''$ to $3\frac{1}{2}''$	square or round.
Flat iron ,,	1″ to 7″	broad.
Plate iron ,,	$\frac{1}{4}''$ to $\frac{3}{4}''$	thick, rolled out of bars.

Plate iron, if thinner than $\frac{1}{4}''$ is called **sheet iron**; 3″ angle iron should be $\frac{3}{8}''$ **thick, not** less; and $3\frac{1}{4}''$ angle iron not less than $\frac{1}{2}''$ thick.

97. Iron **weighs** 10 lbs. per **yard long,** for every square inch in the section; or if reduced to $\frac{1}{4}''$ plate it weighs 10 lbs. for every **square foot** of plate.

98. When an iron girder is exposed to **concussion,** as with a rolling load, 7 **times** the calculated necessary **strength** should be given. As a rule, the **strength** should be sufficient for 4 times the total weight of the bridge, and 4 times the greatest moving weight upon it: for wrought-iron bridges the rule is, that the structure itself with the greatest load upon it shall not produce a greater strain than 5 tons per square inch.

99. In calculating **strength** of **girders** for railway

bridges, allow for a rolling load 2 tons per foot run, up to 20′ span; over 20′ span $1\frac{1}{2}$ ton will suffice.

100. In railway bridges the girders are **tested** first by leaving a maximum dead **weight** upon them for a time, and again by driving a heavy train across at a high speed, noting the **deflection.**

101. The safe deflection of a cast-iron beam is one-third of its ultimate deflection and $= D = \cdot 02 \times \frac{l^2}{d}$.

102. T iron is 4 times as strong under load when turned so ⊥, upside down.

103. A **Warren girder** is the simplest form of lattice girder; it combines economy, portability, and simplicity of construction; but is not well suited for concussion.

104. There are 20 different kinds of iron **ore,** but very few suited to the purposes of the manufacturer, the great drawback is the difficulty in melting. The goodness of an ore depends on its **quantity, quality,** and **cost** of **production**; the best ore is the **oxide** or the compact carbonate of iron, chiefly combined with clay. This oxide of iron is always found near coal measures.

105. The ore is **slowly roasted** before it is smelted, to drive off the sulphur; the roasting may take months to perfect. The roasting is conducted in **kilns** or mounds; 40 or 50 tons can be turned out from the kilns in the course of the day; a free circulation of air is kept up to prevent the ore from melting.

106. **Clay** or **lime** may be used as a **flux** in smelting iron, according to the nature of the ore; the best **fuel** is that which has least sulphur in it. Coal is improved by coking. If wood is used, the harder and heavier it is the better; 100 lbs. of wood will give 20 lbs. charcoal; the quantity of **flux** will vary with the ore, say, 15 cwt. of limestone to 1 ton of iron. The best iron is made by using wood charcoal.

107. The **higher the temperature of a blast furnace,** the more iron is yielded and the less fuel is consumed in the process; there is commonly a pressure of $\frac{3}{4}$ lb. to $3\frac{1}{2}$ lbs. per square inch caused by the air-blast, and if the air has been previously heated to 500° or 700° Fahrenheit it is all the more effectual in promoting rapid combustion.

108. The **smelting furnace** is built of pure **sandstone**; the upper part may be of brickwork, enormously strong in order to contain a mass of 150 tons within it; the shape of the **lower** part of the furnace is of the utmost importance, the **bouches** of the furnace being made wider or narrower according as the ore is more or less easily melted. The fuel, the ore, and then the flux are thrown in; 4 tons of fuel will melt 1 ton of iron with the help of 15 cwt. of flux.

109. The **scoria** affords a test how the furnace is working, as it flows over through a hole made for the purpose. The melted ore runs out as **pig iron** before the scoria has risen high enough to cover the dam stone.

110. The **qualities** of iron differ greatly and depend much on the manner of preparation: **hot-blast irons** are usually smelted with coal, **cold-blast irons** with coke, hence cold-blast iron has the advantage.

Welsh iron is stronger than Scotch, and there is more of it, but Scotch is cheaper because the Scotch hot-blast irons are so fusible. All irons improve by mixing. The different qualities are distinguished by numbers, No. 1 being the highest priced and softest; it is three times the price of No. 3; it is very liquid, fine for castings, teeth of wheels, &c.; it is thin, and takes a sharp edge, and shows a large coarse granular shining appearance when broken.

No. 2 is not so soft or fluid as No. 1, but no clear line

exists between the qualities. Nos. 1 and 2 will not polish.

No. 3 polishes well, and is used in architecture for girders, &c., where strength is required.

No. 4 is stronger still; it is used for cannons, cylinders of hydraulic presses, and piston rods of steam engines.

No. 6 is called **white iron**, and is so extremely hard that it can scarcely be used.

No. 3, or medium iron, makes the best wrought iron. No. 1 has too much, No. 6 too little, carbon.

111. When the iron is intensely heated it passes through the liquid state and becomes **stiff**; in this state it is worked in the **reverberatory puddling furnace**; about 4 or 5 cwt. are introduced at a time, worked up into a large ball of spongy iron containing slag, silica, and other impurities. **Steam** has been driven through from below, that when decomposed the oxygen might combine with the carbon, leaving the hydrogen to combine with the sulphur; electricity has also been tried, but hitherto no device has succeeded in lessening the great manual labour of puddling properly, so as to bring every part of the iron in its turn into contact with the air.

112. When the iron has been reduced by the puddling furnace to a **spongy** consistence, it is **shingled** under a **tilt hammer**, to squeeze out the impurities, which amount to about 12·5 per cent.

113. The next process is generally performed by women; in it the **tilted** iron, broken up into bits, is piled into masses, introduced into a piling furnace, heated to a **welding** heat, and rolled out into bars, straightened, and stamped.

114. There are five kinds of **manufactured iron**, common iron, best iron, best best iron, charcoal iron, and scrap iron. **Cable** iron is **best iron** cut up and

repiled; it costs 20*l.* per ton. **Scrap iron** has many kinds mixed in it. Domestic utensils, trays, horse-shoes, nails, &c., are made of **charcoal iron. Wires** are made of No. 3 pig iron, which is by far the most ductile and malleable kind of iron; the wire is made by drawing out the bars through a series of holes gauged gradually less. The usual defects met with in this iron are **cold short** iron, and **red short** iron. (Nos. 13, 14.) **Cold short** iron arises generally from over-heating, or over-working after heating. **Red short** iron is chiefly owing to the over-richness of the iron, and the presence of impurities; the remedy for this is to mix it with a leaner quality of iron.

115. The **change of texture**, from **fibrous** to **granular** and brittle, which iron undergoes when subject to concussion, as in cranks and engine axles, is fortunately easily remedied by heating it red hot and cooling **gradually**, this completely restores the ductility and malleability.

116. The best iron for making **steel** is that called hoop L iron. The **Sheffield steels** are the best; the bars of iron are heated from 5 or 6 days to 10 or 12 days for strong steel; the processes being, the **cementation** process, in which a layer 1″ thick of carbon is placed on the floor of the furnace, over this a layer of Swedish bar iron, and so on alternately; it is heated for 5 days, and is then called **blistered steel**, which is used for blacksmiths' tools, quarrying and rough tools generally. **Steel** is harder, more elastic, and more easily fusible than iron.

117. Tilted steel is much better than blistered steel; it is made by heating the blistered steel red hot, and hammering with extreme velocity; by this process the steel obtains a long thin fibre, and becomes tough and **close.**

For **shear steel** see (No. 52).

118. To make **cast steel**, blistered steel (No. 116) is broken up and placed in crucibles, generally 14 lbs. at a time, and covered carefully over; charcoal is then put on, and the mass is melted, stirred, and poured out into the mould.

119. Cast steel is used for all the more important tools of the carpenter, and for engineers' tools.

120. Whenever a **moulding** is to be made, first a drawing is necessary, then patterns have to be constructed, generally of **yellow pine**, because this wood is firm, soft, easily cut, free from knots and grain, works cleanly, is cheap, and above all resists the effects of dry rot; where a **harder** wood is wanted, mahogany, plane, or pear wood may be used; the great object is to get a wood that will not **warp**.

121. Green sand for moulding is composed thus:—

$$\textbf{Green sand } 1\cdot00 = \begin{cases} 0\cdot95 \text{ parts of pure silica.} \\ 0\cdot04 \quad ,, \quad \text{pure iron.} \\ 0\cdot01 \quad ,, \quad \text{alumina.} \end{cases}$$

Green sand is not acted upon by acids or hot metal; it is **open**, that is, its pores allow gases to pass readily through; it is soft and easily takes the form of the mould; moreover it will allow **tons** of metal to pass over it in a liquid state without losing its form.

122. It is most important to **ventilate** moulds properly; this is usually done by making the mould in two halves, laid in two equal boxes fitting together face to face: a hole is then drilled at **each** end, and the metal introduced at the lower end, allowing gases, &c., to escape by the hole at the upper end.

123. A **parting** of dry sand is sprinkled to prevent adhesion between the two boxes.

124. In **dry sand moulding** coal dust is mixed, to

open the sand (121); pipe-clay and charcoal-blacking are dusted over the pattern; clay is used with dry sand to promote the baking, the pattern is then painted.

125. Pounded fire-brick has been used instead of sand for casting guns, the pattern being moulded in two boxes, burnt red hot, and painted. **Decomposed granite** ground and mixed with pipe-clay water is a good material for casting.

126. In **loam mouldings** no pattern is made use of, but the lathe bed and vertical spindles applied direct, taking care that the dumb tracer passes over each part of the model. **Loam** is a mixture of sea sand and brick clay.

127. In **bell casting**, or such large work, **tan ash** is used as a parting.

128. In a **cupola** $2\frac{1}{2}$ cwt. of fuel will melt 1 ton of iron, which would have required 12 cwt. in an ordinary air furnace.

129. In making musket barrels, fire irons, saws, scissors, and many implements, wrought iron is the material used, and it is subsequently heated for 3, 4, 5, or 6 hours in a furnace with bits of leather, bones, or anything which would give animal charcoal, mixed with salt and vinegar; all being enclosed in loam, or in an iron box; the whole is first dried on the hearth, then heated red hot, **and no more**; the iron is plunged into cold water to harden the skin, and afterwards polished. This process is called **case-hardening**. The use of it is that keys or other case-hardened articles combine the toughness of the wrought iron with the hardness of the steel skin. The iron may be case-hardened by making it red hot, and sprinkling it over with ferrocyanide of potassium.

130. An attempt has been made to **cast** iron **tubes** by centrifugal force, but in spite of expensive machinery,

it has failed; and the process remains as below. Suppose the **tube** to be formed from a bar of **stub** iron, or ribbons of old horse-shoe nails welded together, beaten round a **mandril**, leaving an overlap at the edges, which are subsequently **lap welded** together, the joint being upwards as the tube lies. The chief point is to obtain **clean** smooth surfaces of contact for the **welding**; zinc, copper, lead, or any other impurities, foul the fire, and the welding will not hold. The edges being clean cut and **scarfed**, they are overlapped and put into a special welding furnace, where the fire is at one end, and the flame led by a current of air to bear upon the unwelded line of the joint. The tubes, when welded, are cut into lengths by **cold saws** (that is by saws unprovided with teeth, but revolving with enormous rapidity).

131. The **welding** point of **cast** iron is so near its melting heat, that it is very difficult to weld it, for instance, to put collars on to a cast-iron shaft. **Wrought** iron is easily **welded.** **Cast iron** has been welded by being brought to a white heat in a mould, in which state steel, calcined borax (flux), and dust of cast iron are strewed over it.

132. **Iron** turned into **cast steel** increases its **value** 500-fold.

1*l.* **worth** of iron will make into 150*l.* worth of scissors, or 657*l.* worth of penknives; 2*d.* worth of iron will make into 2763*l.* worth of watch-springs.

133. **Homogeneous** metal is the best material for the tubes of **boilers**, being light, strong, and not easily oxidized. The difficulty is to secure the ends of the tubes into the plates, as the junction must be thick comparatively, and hence the unequal transmission of heat causes the tube and its collar to disagree, so that the boiler "pulls itself to pieces."

134. The use of **tubes** in a boiler is to lighten the

boiler and **hasten** the generation of steam by offering a larger heating surface.

135. A **low** fire is never economical, the same quantity of **fuel** burnt at a **high** temperature would do more work. A **chemist** might get 14 lbs. of water turned into steam by 1 lb. of fuel: but in **engineering**, the most is 11 lbs. of water turned into steam by 1 lb. of fuel.

136. The very worst description of **boiler** costs only 1*s.* 5*d.* per 100 gallons of water turned into steam, that is 1*s.* 2¾*d.* fuel + 2¼*d.* wages. **Fairbairn's** boiler costs 10¼*d.* to 11*d.*, that is 8½*d.* to 10¼*d.* fuel + 0¾*d.* to 1¾*d.* wages.

137. **Boilers** have been tried of a variety of metals; iron boilers are the best, though **copper** conducts heat better, and when old is as good as new. Copper is five times as expensive as iron, and at a temperature of 500° only half its strength. The **best** irons for boiler plate are the **Lowmoor** and Bowring irons. Boilers can **not** be **welded**, as they crumple in the process, so the joints have to be riveted.

138. **Locomotive** engines would always be estimated by a mechanical engineer in **detail**, each spindle, crank, &c., separately, totalled up, and contingencies added; but for a rough and ready approximation such work might be quoted at 100*l.* per ton, gross weight.

139. A **distance** of **200 miles** may be taken as an ordinary day's run in practice for a locomotive; and for every 200 miles run, it requires to go into the engine shed for some trifling repairs, which are easily performed by a skilled workman.

140. With **road steamers**, or **traction** engines for ordinary roads, the jarring wear and tear is naturally far greater and the necessity for skilled daily repair and adjustment all the more imperative. Such daily repairs

may consist merely of tightening screws, easing bearings, repacking, &c., but they may neither be neglected nor postponed with impunity.

141. Of **fuels**, **Newcastle** coal **cakes** well, and is therefore suitable for marine engines, but unless constantly looked after and stirred, it **smokes** immoderately.

142. **Welsh** coal gives little or no smoke, it is friable and contains much carbon.

143. **Patent coal** is made of coal tar, sawdust, and coal dust; it is formed in blocks, and therefore packs well, but it smokes immoderately.

144. **Anthracite** burns with an entirely **local** intense heat; it does not **throw out** much heat and is a troublesome coal to manage.

145. The following are the principal **causes** of boiler **explosions**, and their **remedies**. First, want of strength in the material or **design**; a weakly **shaped** boiler does not always **give way** at its defective point, it may merely gain a leverage there on some other naturally strong point, hence the immediate cause is the more difficult to trace. **Stay bolts**, if used, require frequent cleaning, and the workmen **forget** to replace the **pins**.

(*c*) Using too **high a pressure** for economy's sake.

(*d*) The **absence** of **safety** valves and steam gauges.

(*e*) Having **one safety valve** amongst many boilers, and forgetting the "shut off" valve when one of them has been closed to clean it.

(*f*) **Sticking** of the **safety** valve.

(*g*) **Exhaustion** or deficiency of **water** in the boiler, allowing the tubes to become **red hot** and decompose the water or convert it too instantaneously into steam.

(*h*) **Dirt**, sediment, salt, or calcareous matter, which the water **deposits** in **quiet** corners; this sticks to the plate as a crust, the plate gets red hot under it and

burns, or the cake cracks and the water assumes the **spheroidal state** on the red-hot iron.

(*i*) **Priming** or passing over of **water** with the **steam**, is caused by scarcity of water, dirt in the boiler, or sudden **transition** from salt water into fresh, as a much higher temperature is required for salt water than fresh; in this case there is a knocking heard.

(*k*) **Feed pumps** being out of order, stop cock being left open.

(*l*) **Superheating** the steam.

146. Explosions nearly always occur just **after** the engine has been set at work.

147. Boilers should be **proved** every day by being filled with water, if in cold weather the water should be at 200° Fahrenheit, as iron is very brittle under low temperatures; a few strokes of the forcing pump will now produce a pressure of 4 times the working pressure; the boiler should stand this for one hour without leaking, before work.

148. Sulphate of lime is very hard to get rid of and very destructive to the eyes of a boiler; **salt** is hard to get rid of: **brine** collects at the **bottom** in still water, or at the top when it is in a state of ebullition.

149. Hence scrupulous **cleanliness** and an attentive **supply** of water are the two best safeguards against accident; double safety valves and glass gauges are also used, one safety valve being inaccessible to the driver.

150. Steam may be heated up to **any temperature**, and it more than **pays** for being superheated, by the extra work it does: The **expansive** force of steam is brought into work by **confining** it; the **elastic** force of steam is worked by shutting it off at half or quarter stroke, the feebleness and irregularity of the result being modified by the use of a fly wheel. There is a third force, namely, the **condensive** power of steam, in form-

ing a vacuum, but this force is not applied in high-pressure engines.

151. The **D slide** which works over the **steam ports,** admitting the steam from the boiler through the steam pipe into the working cylinder, has the lead slightly over the piston at each end, being worked by eccentrics so adjusted as to shut the ports and form a steam cushion just before the piston arrives; by **link motion** this can also be done when the engine is reversed.

152. In all **locomotives** there are two engines, having their cranks inclined at an angle of 90° so that the **dead point** or "mechanical dilemma" is never simultaneous. The driving wheels supply the place of fly wheels. Say each **driving wheel** is 16′ in circumference, then it requires four cylinders full of steam to move 16′ along the rails; or taking the result of practice, say at a speed of 27 miles per hour, 6400 cylinders full of steam would be wanted.

153. In order to **generate** all this quantity of **steam rapidly** enough, the cylindrical portion of the **boiler,** which may be 12′ long × 3′ 6″ diameter, made of the best Lowmoor iron, is furnished with 120 to 150 **tubes,** $1\frac{1}{4}$″ apart, running throughout its length from the **fire box** to the **smoke box**: through these tubes the fire and heated air pass on their way to the funnel.

145. The **fire box** is double, the inner one contains the fire, the outer is surrounded by the water. The inner is strengthened by stays at 4″ intervals, made of $1\frac{1}{4}$″ copper, screwed in and riveted over; the top is strengthened by stays and bars, and has a leaden safety plug in it which should melt at 400° Fahrenheit, if the water ever falls below its level. Such a plug valve should be changed every 3 months, else the lead turns hard and will not melt.

155. The **smoke box** is at the other end of the boiler;

it is provided with doors for **access** to the boiler, in order to clean it; the small tubes constantly want the soot cleared out of them, as their efficacy depends entirely on their **cleanliness**; the smoke box has a funnel up which a draught is created by the discharge of the steam producing a partial vacuum in the smoke box, upon which the heated air rushes in through the tubes from the fire box: this rush of heated air is very considerably augmented by furnishing the ash pit with two doors, opening downwards, one placed **fore** and the other **aft**, which are entirely at the command of the stoker, so as to produce a strong artificial current if wanted. The pipe which discharges the steam and causes the rush of hot air is called the **blast pipe**; the funnel is **capped** with a netting, to stop **sparks** and cinders.

156. A good **boiler** ought to stand a **pressure** of 400 to 500 lbs. per square inch: each engine has two **safety valves**; one of them, being locked up beyond the control of the driver, is kept down by a strong spiral spring; the other works by a weight lever and balance, and can be adapted by its graduated arm to any required pressure. The engine is also provided with a glass gauge.

157. The **whistle** consists of a tube having a stop-cock connection with the boiler; the steam, rushing through this, impinges upon the concave surface of a bell hemisphere through small openings, and thus produces a tone which can be modified by the driver.

157a. The **steam pipe** is made of **copper.** Three **bars** run from the smoke box to the fire box, and to these bars all the **machinery** is attached. A locomotive engine is always furnished with 2 **pumps** for forcing water in, and it requires considerable skill to work them, as the engine's **demand** depends on the speed

very much, and the speed indicated by the gauges is modified by the gradients.

158. The **pumps** have cocks, to show if anything should go wrong with them: they are made of iron, and draw the water from the tender; a skilful driver will jockey his engine, working both pumps in going down hill and neither in ascending. There is a contrivance by which the enormous pressures against the upper and lower arms of the **D slide** are made to counterbalance each other; the invention of the **link motion**, as it is called, provides for the difficulty of making the eccentric take the lead of the piston in both direct and reverse motion.

159. There is an **oak frame** immediately surrounding the **boiler**, and 6 strong iron plates connect the machinery with the framing. Whether the engine have 6 wheels or 4, there are springs adjustable by screws attached, to allow a distribution of so much load to each wheel.

160. In order to economize heat, the **boiler is packed** with a thickness of 1″ **cowhair felt**; this, again, is surrounded by wooden **lagging**, bound by brass bands.

161. **Wrought iron** becomes crystalline under vibration and **concussion**; cast iron is not affected. **Cast** iron is generally used for struts, columns, and resistance to **compression** or **crumpling**; **wrought** iron for toughness to resist tensile force.

162. The **simplest girder** is the **straight cast-iron** girder, its length is practically limited to spans of 60′. **Cast-iron built girders** with wrought-iron tension rods are used from 60′ to 120′ span. **Hollow girders** are made of boiler plates riveted together; they generally have the top and bottom double, the former being of cast-iron plates. Such tubes as those of the Britannia tubular bridge suit a span of 462′. (No. 79.)

163. Girders for tanks, or such invariable **steady loads**, may be calculated to bear **3 times** the weight; girders for a railway must be designed to bear 7 times the actual load.

164. An **engine** will **weigh** 22 tons, and the **tender** 10 to 12 tons; some broad-gauge engines weigh 32 tons alone, but such a weight **flattens** the rails.

165. Cast iron is about half the **price** of wrought iron. In **ordering girders** specify the **breaking weight,** not the **kind** of iron alone; let them cast one **more** than the number required; select the most unlikely looking for proof; load it, test it, and, if it comes up to the description, accept **all** the others.

166. The **section** of the top **flange** is generally $\frac{1}{6}$ of the bottom one for a steady load, or $\frac{1}{4}$ of it for a railway bridge. When the girder is made of separate castings it should have **tension rods,** in addition to bolts.

167. Scotch hot-blast iron mixes well with Blaenavon, Welsh, and old iron; the Scotch should be half black band and half hæmatite.

168. The roadway is borne on **joists** resting on the **bottom flanges** of the **girders.** Clear grey iron is the strongest for **girders**; the best mixture is, perhaps, $\frac{1}{3}$ Welsh + $\frac{2}{3}$ Derbyshire, or Yorkshire, or Shropshire.

169. An ordinary **train weighs** about $\frac{5}{8}$ of a ton per foot run; $1\frac{3}{4}$ ton is the greatest weight which can come on a foot run of single track.

170. The only use of **bolts** through the **flanges** is to prevent lateral motion.

171. From 120′ up to 200′ **span** the bowstring girder is the best that can be used; the bow to be of cast iron, and tie of wrought iron.

172. Six and a half tons is the safe practical limit per square inch of sectional area for **tension** of boiler

plates. The **joints** may be single riveted, double riveted, or **cover plated** (equivalent to fished joints). A single-riveted joint will only bear a tension of 3¼ tons per square inch, a double-riveted joint 4½ tons.

173. A cover plated **joint**, provided the plates be equivalent in combined sectional area to the girder ends they unite, will bear a tension of 6 tons per square inch, they are generally from $\frac{1}{4}''$ to $\frac{1}{2}''$ thick each.

174. A **wrought**-iron **girder** is usually only about half the weight of a **cast**-iron girder. **Wire** is a bad substitute for wrought-iron rods as ties, the tension being unequal.

175. The actual **strength** of **wire** ropes, **chains**, &c., is given in **Molesworth's** Engineering Pocket-book. (XIII., 235.)

178. A **difference** of 0·078″ in the lengths of 18′ **rails** is not allowed.

179. Narrow gauge is preferable for the transport of goods, but greater speed may be maintained on **broad-gauge** lines.

180. Girders of any shape may be generally made by joining flat iron (either as **web** or **flanges**) by means of angle iron. The holes are punched by machinery, the parts put together, and held by bits of round iron; the rivets say for $\frac{10}{16}''$ iron plates are cut by a machine into lengths of 3″, these are made red hot, pushed through the holes, and punched by an eccentric, or hammered by hand, so as to form each end of the rivet into a knot of iron.

181. Machine riveting can, however, only be applied to **girders** in the **first** stages of their manufacture; when the flanges have been bolted on, manual labour alone is applicable, owing to the complexity of the shape.

182. Unless iron ore contain more than 25% of metal it will not well pay the working.

183. Copper is too **expensive** (No. 4) to be used much as a building material (137). It is obtained by a series of operations from copper **pyrites**, a sulphide or sulphuret of copper and iron. Ore containing only 2 or 3 per cent. of metal is still worth working, owing to the value of the metal when extracted.

184. Zinc, or spelter, is obtained from its carbonate or silicate (known as calamine); or else from its sulphide (zinc blende). Zinc is used for pipes, gutters, and roofing, and for galvanizing sheet iron.

185. Lead is almost entirely derived from the sulphide (galena); it is used for water fittings, but is apt to poison distilled, rain, or soft waters; if the water contain carbonates or sulphates, especially of lime, this action is prevented. Lead contracts too much at the moment of solidifying to be used for **castings**.

186. Tin occurs chiefly as **tin stone**, or kassiterite, which is a peroxide of tin; and tin pyrites, a sulphide of tin.

187. Coal may be looked for where the geological formations numbered 3, 4, and 5 in the table (IX., 96), are found cropping out.

188. Iron may be looked for where the formations indicated are from 2 to 4. (IX., 96.)

189. Lead may be found chiefly between the Devonian and Trias, or from 3 to 7. (IX., 96.)

190. Copper is commonly found about disintegrated granite, schistose rock, and clay slate.

191. Tin stone occurs in granite, gneiss, clay slate, chlorite and mica slate formations, consequently it may be looked for with **copper** where the geological formations 1 to 3 show themselves. (IX., 96.)

192. Iron girders when used for **roofs** or floors are

nearly always double **T** shaped or **I** shaped, made of **boiler plate**, connected at the edges by angle iron riveted together.

193. The calculation used in practice for the **strength** of such an **iron girder** is to allow a strain of 5 tons per square inch of sectional area for wrought iron, the depth being made one-twelfth ($\frac{1}{12}$) of the clear span; for the **weight** of the girder itself, **ten times** the sectional area in inches gives the **weight** per lineal yard **in lbs.**

CHAPTER IX.

MASONRY AND STONES.

1. **Stones** may be regarded either **chemically** or **structurally**, that is with reference to their elementary composition, or their texture and mechanical features.

2. The **structure** of stone is either **stratified** or **unstratified** according as it consists, or does not consist, of **flat layers.**

3. **Unstratified** rocks, apparently of **igneous** origin, cooled from the melted state under pressure, are **granite, basalt, trap rock** (in boulders), **syenite.**

4. **Stratified** rocks, apparently deposited from **water** are gneiss, mica slate, talc, quartz, flint, hornblende slate, sandstone, clay slate, marble, oolite, dolomite.

5. **Granite** in the unstratified form is of the same composition as **gneiss** and **mica slate** are in the stratified form.

6. **Unstratified** rocks are in blocks, which separate as the rock decays, and get rounded into **boulders.**

7. Amongst varieties of structure in **unstratified** rocks are the **porphyritic** and **cellular,** which are distinguished by detached crystals and cells or air-holes.

8. In **stratified** rocks, a **fault** means an abrupt alteration in the level of the strata.

9. A **vein** is a crack or fissure; a **dyke** is a mass of unstratified rock in a vein of stratified rock.

10. The hardest and **best stratified** rock, though

most disturbed, may be looked for near unstratified rock.

11. The **laminæ** of stone may be parallel or inclined, or even perpendicular to the strata in which they lie, but stones of laminated structure should be laid flat in building, never on edge in a building (Nos. 43, 56, 66), else flakes split off in time.

12. **Stratified** rocks may be of the following descriptions:—

1. **Compact crystalline**, such as quartz and marble.
2. **Slaty**, such as clay slate and hornblende slate.
3. **Granular crystalline**, such as gneiss and all kinds of sandstone.
4. **Compact granular**, such as blue limestone.
5. **Porous granular**, such as oolite, chalk to Bath stone.
6. Conglomerate, such as pudding stone.

13.

An even fracture indicates	crystalline structure.
Sharp projections indicate	granular „
Slaty fracture indicates	laminar „
Conchoidal fracture „	tough compact structure.
Earthy „ „	soft structure.

14. **Stones** are constructed of **minerals**, minerals are composed of **earths**, and earths are combinations of chemical **elements**.

15. The principal **earths** are four in number.

Earths	1. Silica, found as	quartz, sand, flint pure.
	2. Alumina „	ruby, sapphire, clay as a silicate.
	3. Lime „	marble, chalk (carbonate).
	4. Magnesia „	dolomite (double carbonate of lime and magnesia).

Alkalies	Potassa or potash.	Acids	Carbonic.
	Soda.		Muriatic.
	Ammonia.		Sulphuric.
			Nitric.

16. The principal **minerals** formed by the above **earths** are five in number.

Minerals

- Quartz is found as sand, flint, rock-crystal; and consists of pure silica.
- Felspar is found as white or pink crystals in granite, &c.; and consists of silica, alumina, and potash.
- Hornblende and augite are found as greenstone in trap rock; and consist of silica, magnesia, and lime.
- Mica is found as mica; and consists of silica, alumina, potash, oxides of iron and manganese.
- Limestone is found as limestone, marble, chalk, shells, dolomite; and consists of carbonate of lime, silica, and alumina.

17. **Building stones** may be conveniently classified according to the **earths** or **minerals** (Nos. 15 and 16) of which they are composed.

Stones

- (1) Silicious or **pebble** stones—such as granite syenite—gneiss, mica slate, trap, basalt, quartz, flint, sandstone, hornblende slate.
- (2) Argillaceous stones or **clay** stones—such as porphyry, clay slate, grauwacke slate, felspar.
- (3) Calcareous or **lime** stones—such as marble, chalk, oolite, dolomite.

Of the above stones, the (1) **silicious** or **pebble stones** are characterized by a crystalline granular structure; they exist in the

Unstratified form as granite—consisting of quartz, felspar, mica (hornblende).

Unstratified form as syenite—consisting of quartz, felspar, hornblende (mica).

Stratified form as gneiss and mica slate, which are of the very same composition as the above but stratified.

Greenstone, whinstone or **trap rock**, and **basalt**—consisting of crystals of hornblende or augite, with felspar unstratified.

Quartz and flint—consisting of pure silica.

Common **sandstone** consists of grains of sand cemented by a compound of silica, alumina, and lime.

The strength of sandstone depends on the nature of the **cement**; if pure silica it is strong and durable, if much alumina it is weak, and resembles felspar or clay stone.

(2) The **argillaceous** stones are—

Porphyry, consisting of a felspar matrix, soft or hard, with crystals of felspar, quartz, hornblende, &c., in it.
Clay slate, consisting of laminated clay.
Grauwacke slate, consisting of laminated clay with sand, mica, &c., in it.

(3) The **calcareous** or lime stones are—

Marble, which is a compact crystalline carbonate of lime.
Common limestone, which is a carbonate of lime, with more or less sand and clay added.
Oolite or granular limestone, which is carbonate of lime, in shells, cemented with lime, silica, alumina, and sand.
Dolomite, which is like marble when hard, it is a double carbonate of lime and magnesia.

18. Of **silicious** stones, **granite** is used for massive masonry.

Gneiss, chiefly for flagstones in paving.

Whinstone, **trap**, and **basalt** for metalling roads and paving.

Quartz is unworkably hard. **Flint** is found as pebbles in chalk beds, and used for concrete as well as for building.

Hornblende slate is used for flagstones.

Sandstone when in thick layers is used for all kinds of building, it can be cut with a saw.

19. Of **argillaceous** stones—

Porphyry is only useful for ornamental work. **Clay slate** for lining cisterns and for roofing houses.

20. Of **calcareous** stones—

Marble is only used for ornamental work.

Compact limestone, white, greyish white, and whitish brown, are used for building.

Oolite or granular limestone varies much in quality from **Bath stone** or Portland stone to soft chalk. Exposure to acid disintegrates it.

21. To test the **durability** of stone in the absence of existing monuments, look to its specific gravity, texture, and non-absorption of water; the more compact, heavy, and non-absorbent qualities are, cæteris paribus, the more durable.

22. For the **preservation** of stone, coal tar, solution of paraffine in pitch oil, drying oil, paint, silicate of potash or silicate of lime are used in solution.

23. Masonry is built in parallel horizontal **courses**, with the largest stones lowest; **laminated** stones on their natural bed (No. 11), and all **joints** well flushed up solid with morter.

24. A **stone** when placed in a building has two beds, two sides, one face, and one back. The surfaces of contact are called **joints**, hence the above stone has two bed joints, upper and lower, two side joints, and one back joint.

25. A vertical **joint** should in no case be directly **over** another joint, otherwise there would be no vertical **bond.**

26. Each **stone** should be not merely dipped, but **well saturated** with water, before being laid in morter.

27. Where a **convex** surface presses against a plane or convex surface, the joint is said to be **open**; where a **concave** surface presses against a plane or concave surface, the joint is said to be **overflushed.**

28. Stone may be rough, hammer dressed (59), droved with the inch tool, or chisel dressed.

29. Masonry may be ashlar (perpend ashlar), block in course, coursed rubble, or random rubble.

30. Ashlar masonry is cut square in blocks whose dimensions in terms of their depth d, may vary from $d \times 3\,d \times 1\frac{1}{2}\,d$, to $d \times 5\,d \times 3\,d$.

31. The bed joints, side joints, and face, in **ashlar** masonry are cut square by first running a chisel draught

round the edges, next diagonals, and then reducing each face to the plane of the chisel draughts by means of a straight edge.

32. In **ashlar** masonry, each stone should first be fitted into its place dry before it is laid in morter.

33. **Bond** in masonry consists in breaking joint (No. 25), this ties the whole structure together, and distributes pressure.

34. **A stone or brick** laid with its length **along** the wall is called a **stretcher,** if laid **across** the wall it is called a **header.**

35. The **strongest bond** (Nos. 33, 25) is of alternate headers and stretchers in each **course** of stones along the wall (23) face. Ends of headers should at any rate form not less than $\frac{1}{4}$ of the whole area of the wall face.

36. **Quoins** are corner stones, and are at once both **headers** in one wall and **stretchers** in the other.

37. The **thickness of morter** in **ashlar** joints should be about $\frac{1}{8}$ of an inch. The quantity of morter by measure is to the stone in **ashlar** masonry as 1 : 8.

38. **Ashlar** is used for piers, abutments, arches, and parapets of bridges; for hydraulic works; for **facing** rubble, &c.; for quoins, string courses, and coping.

39. There must be **a chisel draught** square and sharp round the face of each stone that it may be accurately set.

40. In **ashlar** masonry the depth of a course is not less than 12″.

41. **Block in course** masonry differs from ashlar only in the depth of the courses, which in such masonry varies from about 7″ to 9″.

42. **Block in course** is used for spandrils, wing walls, and to face retaining walls.

43. **Coursed rubble** masonry, the courses are about 12″ deep, each course is approximately levelled before

the next is proceeded with. The **side joints** are not necessarily vertical, but no slope flatter than 60° altitude should be allowed. Stones should never be set on **end** or on **edge** under pressure. (No. 11.)

44. One **quarter** (No. 35) of the **area** of each face should be **headers** or bond stones, these should be so distributed as not to come vertically above one another. (No. 25.)

45. In **inspecting masonry** see that the joints are **fine vertical** and well **bonded**; hollows **not** filled with **rubbish**, bond stones not **dummies**; masons are very apt to build a wall in two unconnected halves, viz., a front and a back, this must **not** be allowed.

46. One **cubic yard** of rubble masonry requires (including waste) 1·20 cubic yard of stone + 0·20 cubic yard morter; say for **rubble masonry**, morter is to stone as 1 : 6.

47. Coursed rubble is used for retaining walls, wing walls, backing of ashlar faces, fence walls, &c. **Random courses** merely mean in **steps**, not all simultaneously levelled. **Common** rubble differs from the above only in not being **coursed.**

48. Common rubble is not much stronger than the morter with which it is built, it is only good for fences, bottoming, or filling in shellwork.

49. Ashlar facing should be rough at the back; **bond stones** rough at both sides and back, they may **taper slightly** in breadth, but **not** in depth.

50. The **rubble backing** should be carried up simultaneously with the face and heedfully adjusted.

51. In estimating rubble masonry with ashlar facing, take out the area of the face × the depth of chisel dressing as **ashlar masonry**, and the remainder as **rubble.**

52. Faced rubble is **not** mechanically suitable for the **abutments** of bridges; ashlar or block in course should be used throughout. Faced rubble is only suit-

able where the pressure is concentrated near the face as in **retaining** walls.

53. String courses, and **collar courses,** are projecting **ashlar-dressed** stones in broad slabs, for various purposes besides ornament. When ashlar is built upon rubble for instance, a **string course** should intervene to distribute the load; as between an ashlar parapet and a block in course spandril or wing wall.

54. Coping is of **ashlar,** its use is to **protect** the masonry below. Coping stones are jointed with hydraulic morter or cement, and **cramped** together with **iron cramps** soldered into holes: or the stones are connected by **dowels** of greenstone or granite of a cylindrical, or prismatic, section.

55. Dowels may also be used to connect the stones in **string courses.**

56. Coping may be of ashlar stones **weathered and throated** to clear dripping; or of rubble stones **on edge,** not flatways; or of clay puddle, or sods, according to the circumstances and importance of the work.

57. Pointing masonry consists in scraping out the morter in the face joints and refilling with hydraulic morter, or with cement mixed (VI., 16) with sand.

58. For **sea walls** the external stones must be **laid in cement** 2″ or 3″ inwards from the face of the wall.

59. The **hammer** with which stones or bricks are **dressed** is called a **scabbling hammer.** Besides being **droved** (No. 28) stones may be **stroked** with a point, or **polished.**

60. Dry stone masonry is only used for **fences,** to face wet slopes, or to drain retaining or other walls: it must be well **thrown back** or the middle will bulge and burst out. (III., 180.)

61. Stones are **raised** by **nippers** working in holes cut in the opposite sides of the stone; or by a single iron plug very slightly **tapered** and driven down a vertical

hole; by a pair of iron plugs in converging holes cut in the upper **bed** of the stone (No. 24); or best by a **Lewis**, a truncated iron wedge or dove tail, in three pieces which can be taken out one by one, but not all together.

62. For **lifting** and **shifting** stones in ordinary buildings, a movable jib crane is used. In large buildings a **travelling crab** or winch may be used; this runs on rails fixed on to strong framework at each side of the building; the rails support the wheels of a large platform spanning the whole building, on which platform the winch stands.

63. All **measurements** should be reduced to **cubic feet**; and all weight to **lbs.**—the effect of introducing **bushels, loads**, hundredweights of 106 lbs., cwts. of 112 lbs., cwts. of 96 lbs., &c., and the various local nomenclatures, is to **facilitate fraud** by the confusion of significations given to one name.

64. For **retaining walls** (see III., 164).
sea walls, &c. (see III., passim).
masonry bridges (see I.).

65. Stone pavements are laid on foundations of 6″ to 9″ hydraulic concrete (VI., 15), or of rubble masonry laid in hydraulic morter, or of three successive courses of road metal each 4″ deep, consolidated by traffic, or three 4″ layers of gravel with a layer of sand 1″ thick above them.

66. The best material for pavement is syenite (18, 19) granite, whinstone or trap rock; **laminated** stones are not good for paving, but if used they should be set **on edge.** (11, 56.)

67. For stone **flagging** and varieties of **paving** see Chapter X.

68. Artificial stone is made by pulverizing 2 parts of white clay, mixing the powder with 6 parts

fine sifted sand, making the whole into a paste with silicate of soda in the proportion of one gallon prepared silicate of soda to each bushel of the mixture; the mass is then thoroughly incorporated in a mill for ten minutes, when it is taken out, a putty-like consistence, pressed into **moulds** of wood, metal, or plaster of Paris, placed upon a bench and drenched with a solution of chloride of calcium, cold; thus solidified the casting is next immersed in a solution of chloride of calcium (sp. gr. 1·4), temp. 212° Fahr. The first drenching or immersion in cold solution may last forty hours, and the boiling four hours: the casting is then allowed gradually to cool, well washed for seventy-two hours in running water, and dried. The **strength** under compression is about 2·5 tons to the square inch.

69. In **measuring** masonry or brickwork it is only to be taken to the **nearest quarter of a foot**, never to inches or decimals: even thus no two estimators will bring out the quantities exactly the same.

70. Hoop-iron bond may be largely introduced into masonry; sixteen strips of hoop iron, 1″ wide $\frac{1}{32}$″ thick, tarred and sanded, laid immediately above the door or verandah arches in four layers 6″ apart, with four strips in each layer, have been found a useful application of the bond.

71. In ordinary building, **good bond** is far more important than **neat** joints, but the joints should always be fairly made. (XIII., 4.)

72. The process of **quarrying** stone in England is thus conducted.

At the **back** of a **bed**, recognized by the wet faces or other local features, a **triangular** hole is jumped having one angle to the rear, this gives a better direction to the blast than a circular hole; in this, 10 lbs. of powder, well placed and tamped with clay, might bring down 600

tons of granite, two-thirds of which at the least are wasted in working.

73. Cranes are used to lift and carry the blocks, which are then split up by men jumping holes in them, say 7″ apart and 3″ deep, into which holes, feathered iron plugs, or wedges, are driven home by a 27-lb. maul.

74. Such **holes** take one man five minutes to make in granite, or three minutes in blue lias limestone. The splitting and blasting is best effected **across** the grain.

75. For **shaping** the granite a 6-lb. hammer and chisel are used; for soft stone a 4-lb. maul and chisel.

76. Ten 3″ holes is the **maximum** per hour: anyone can use the jumper with a little practice. The men are first put to carry rubble, next to work the cranes, then to work the jumper, last to hew stone.

77. The price of the granite at the quarry was 1*s*. 6*d*. to 12*s*. per foot cube, according to style of work.

78. It takes eight or nine men two days, at a cost of 2*l*., to shift the crane.

79. In **blasting**, the object is more to **loosen** and **shake down** masses of stone, than to produce great explosive violence. For this purpose a hole should be jumped till the **bed below** be reached; at the bottom of this hole a charge, say 25 lbs. of powder, is fired, the charge being laid **untamped** between the beds; if this be insufficient the untamped charges are increased until the mass be loosened.

80. If the **beds** have a pretty **vertical dip**, the cranes may do duty for powder and haul them down direct. For charges, see (III., 55–58).

81. For **blasting** in wet situations or generally **under water**, especially if the charge has to be prepared for any length of time before use, the following arrangement is good when a battery is employed to fire the charge.

Place the bursting charge and primer in a japanned tin box, fill in powder through the hole in the top

through which the primer was inserted, pour in dry sand 1″ thick all over, cover this with wet sand or clay, and solder up the hole with a hot iron, place the tin box in a wooden box pitched inside and outside, cover it with tarred canvas.

82. Solder is made of tin and rosin dust.

83. In **stone cutting** the great art is to make the first **chisel draughts** square and true, so as to bound the surfaces evenly which they border; the surfaces are afterwards brought down to the same level, but convexity is preferable to concavity of a surface, as in the latter case the beautiful-looking **overflushed joints** are sure to splinter away.

84. It is **not safe** to use **stone** for resisting considerable **cross** strains, as the seams are so irregular and so difficult to discover.

85. The best **qualities** for **building stone** are hardness, tenacity, compactness; the enemies to durability are chemical **decomposition** of elements, from sea air, impregnated air, or water; natural **disintegration** of particles from frost, alternations of condition, and exposure generally; and **mechanical fracture** by the various strains and stresses to which its mass is subjected.

86. The more **uniform** the **structure** of **stone** looks, the smaller the concretions, the more imperceptible the texture, so much the better is the quality. Rocks containing iron **not fully saturated** with oxygen absorb oxygen readily, especially when exposed to wet; if, however, the iron in such stone be already combined with its full equivalent of oxygen the stone is **extremely durable.**

87. Either **brickwork** or **masonry** in actual building is commenced by the best workman running up **quoins** of four or five courses at the corners, to give bond and line; a string is stretched from quoin to quoin; the

perpends must be perfectly plumb. If the work be in **bricks** the thickness should **measure** in **bricks** and half bricks, or in the length and breadth of one brick, in order to avoid hollows and chips in the structure.

88. The **width** of windows, doors, and other smaller **openings** should also **tally** with the dimensions of the bricks. It is usual in building to specify so many **bricks thick** instead of so many feet and inches, for the reason given in (No. 87).

89. The **joints** should be specified to be **as close as possible**, and the work to be **flushed up solid** with morter; that is, the morter is to be laid with a **trowel** at the ends and sides **as well as** on the bed of each stone or brick, otherwise they are apt to lay the brick on a morter **bed** merely; press it, scrape off what exudes and wipe it against the outside edge, chancing detection.

90. Grouting is pouring thin **fluid morter** on to masonry, letting it soak in and set.

91. One part of a building should **never** be **run up** while another is **low**; the **height**, and consequent weight on the foundations, should be on the contrary kept as **uniform** as possible, all round the building.

92. It is little use **specifying** how morter is to be made or building operations carried on unless the engineer by an active **vigilant supervision** ensures compliance with his directions; otherwise people will do just as they have always been accustomed to do; in fact the more ignorant people are the more difficult it invariably is to convince them that doing a thing habitually wrong does not constitute experience in doing it right.

93. Iron cramps are not a very good way of **binding** stone; plugs, joggles, or dovetailed cramps of slate are preferable.

94. The **natural bed** of the **stone** should invariably be **marked** by the quarrymen before it leaves the spot.

95. Where **stone** and **brickwork** are **mixed** in the same building, the stone must be dressed so that its **dimensions** may tally with those of the bricks; and the joints in such cases will require special attention.

96. The following **list** of geological **formations** may be useful :—

Class.	Order.	Groups.	Depth in feet.
PRIMARY ..	1. Cambrian	Granite, Argillaceous Limestone, Micaceous Sandstone.	
	2. Silurian	Flags, Sandstone, Schist, Quartzose Grit	6,000
SECONDARY ..	3. Devonian, or Old Red Sandstone.	Blue Fossiliferous Crystalline Limestone, Chloritic Slate, Coloured Shales, Marls, Conglomerate, Micaceous Grit	10,000
	4. Carboniferous ..	Compact Limestone, Millstone Grit, Coal Measures, Ironstone	3,000
	5. Magnesian Limestone	Shelly Limestone, Dolomite ..	300
	6. and Red Conglomerate.	Red Sandstones, Marls, and Marl Slate	
	7. Trias, or New Red Sandstone.	Coloured Marls, Sandstones, Conglomerates, Gypsum, Rock-salt	900
	8. Lias	Clayey, Slaty, Bituminous Limestone, Shale.	
	9. Oolitic, or Jura Limestone.	Portland and Purbeck Stone, Kimmeridge Clay, Coral Rag, Freestone, Fullers' Earth, Shelly Limestone, Fossils, Oxford Clay, Septaria, Cornbrash, Calcareous Grit	1,350
TERTIARY ..	10. Wealden Clay ..	Non-calcareous Clays, Sandstones	900
	11. Cretaceous ..	Green Sand, Fossils, Chalk, Corals, Baculite	1,080
	12. Eocene	Gypsum, Millstone, White Conglomerate, Clay, Sand, London Clay	100
	13. Miocene	Yellow Sandstone, Clay, Lignite, Argillaceous deposits	1,250
	14. Pliocene	Loam, Norwich and other Crags, Shelly Sand, Calcareous Conglomerate	
QUATERNARY	15. Post Pliocene, or Glacial.	Silt, Shells, Sand, Lignites, Gravel, Clay, Limestone, Casts of Shells	100
	16. Recent	Corals, Skeletons, Pottery, Shells, Peat, Calcareous Grits, Gravel, Sand, Mud.	

The **depths** are the average for England; they vary in each locality.

97. Where the **weight** of a building bears upon **points** at intervals as in a **colonnade**, the **foundation** is made **continuous**, with inverted arches under each opening.

98. Cornices and **string courses** are used to conceal the offsets on the outside of walls of buildings.

99. The only way to avoid **cracks** over doors and windows in a building is by well-built **inverts** under the **openings**, thus connecting the piers.

100. Much of an **arch** may be formed by **corbelling** out from the **piers**, the bricks are laid flat and their ends, at the spring, cut to form a skewback.

101. Flat and **relieving** arches are preferable to timber **lintels** everywhere; but if the lintels are adopted nevertheless, their ends should rest on wooden templates or slabs the **whole** thickness of the wall.

102. Walls are little liable to give way by **crushing**, if so the working load may be allowed at $\frac{1}{8}$ of the crushing load: in practice, however, they are much more apt to give way by **overturning**.

103. Hence it is specially necessary to see that no horizontal thrust from an uncompensated truss roof, or rafter couple, tends to overturn an unbuttressed or unbraced wall.

104. The best **rule** for **thickness** of a house **wall** is more clear when exemplified than enunciated: suppose the wall 36′ high, divided into 3 stories, each 12′ high, and the cross or bracing walls 24′ apart; take one-tenth of the height to start with

$\frac{36}{10} = 3 \cdot 6$, and reduce it thus $\frac{3 \cdot 6 \times 24}{\sqrt{36^2 + 24^2}} = 2'$ thick for the lowest story; then

$\frac{24}{10} = 2 \cdot 4$, reduced, $\frac{2 \cdot 4 \times 24}{\sqrt{24^2 + 24^2}} = 1 \cdot 7'$, nearly, for the second story;

and $\frac{12}{10} = 1 \cdot 2$, reduced, $\frac{1 \cdot 2 \times 24}{\sqrt{12^2 + 24^2}} = 1 \cdot 4'$, nearly, for the third story.

The radical quantity represents the diagonal drawn in the plane of the main wall from the top of one cross wall to the bottom of the next.

105. The **actual thicknesses** in construction would be to the nearest **quarter of a brick** thicker than the decimals indicated in (No. 104).

106. **Walls**, especially round **enclosures**, are much improved by being built with **buttresses** or extra thicknesses at intervals; if the wall were 2′ thick and 6′ high, a good proportion would be to have buttresses 3′ thick and 3′ wide at 12′ clear intervals; this adds to both strength and appearance of the wall.

107. **Plain arches** are built with ordinary bricks, and if the curvature be great, the lower edges of the bricks must be in **contact** while the upper edges are open and filled with morter; if the upper edges are very wide apart, broken brick may be mixed with the morter to fill the interstices.

108. Wherever **nails**, pegs, pins, or iron fastenings are to come, **wood bricks** or bond should be built into the wall, to receive them.

109. The best **shape** for a **chimney** is a tapering cylinder; all the lines of the fire-place should converge to the **throat** of the chimney, which should be **contracted** immediately over the fire and widen out again above.

110. **Masonry** brickwork and tiles are also used for **flooring** and **roofing**: in making a **brick on edge** floor, the ground should first be truly levelled or made **parallel** to the intended surface of the floor at a depth of 1′ 3″ below it, and well **rammed**; on this surface a layer of dry **sand** is to be laid 3″ deep to preclude damp and white ants, on this two courses of **brick** are laid **flat** in morter, and one course of brick on edge in morter above it. The upper or brick on edge course is to have very **fine** joints of cement, the surfaces of contact being

rubbed perfectly smooth; when finished, the joints are carefully grouted with thin chunam and water.

111. One course of **brick flat** in (No. 110) may be omitted when a lighter floor is required; the upper course should break joint and may be laid transversely or diagonally. Such a floor should **not be plastered.**

112. The above **floors** are best for **store rooms** or where heavy weights are likely: but for cutcheries, jails, hospitals, cook rooms, &c., **paving tiles** 15″ or 18″ square and 2″ to $2\frac{1}{2}$″ thick are preferred; they are to be **truly** square, **fine** jointed, and laid on the **same** foundation as the **brick on edge** (No. 110), the joints being afterwards neatly pointed with the strongest cement.

113. Flagstones may be laid in the same manner as **tiles** (No. 112), or simply on 6″ of rubble masonry or concrete.

114. Terraced floors are made of morter or concrete merely, and are not suitable for heavy work or much wear and tear: on the bed of **sand** (No. 110) which always underlies the floor proper, is laid 6″ deep a layer of broken brick, the fragments being small enough to pass through a $\frac{3}{4}$-inch ring; over this a little thin morter is poured and well beaten, then a layer 4″ thick beaten down to 3″ of ordinary building morter, the surface of which may be enamelled with **fine lime** laid on with a **brush** and polished with a trowel. The utmost attention must be given to prevent any portion of the work drying before the whole is finished, and also to connect each day's work with the previous work: a thick layer of **wet sand** will serve to prevent too rapid desiccation.

115. On the **bed of sand** (No. 110) a layer or course of bricks may be laid **flat**, and on this again the 6″ of broken brick (114) mixed with dry quicklime; this is mixed dry, laid on, and then saturated with water,

raked, levelled, and beaten down to $\frac{2}{3}$ of its original thickness, finished off with a $\frac{3}{8}$-inch layer of morter laid on, and beaten in, covered by a very thin layer of lime laid on moist and rubbed in.

116. Floors may be protected from **damp** by having **flues** 12″ × 12″ running under them throughout their length, the walls separating the flues may be 12″ to 1′ 6″ or so, according to their height. The ends of such flues should be protected from vermin by iron gratings, or wire netting.

117. Asphalt, whether natural or artificially made by heating powdered **chalk** or limestone with **tar,** forms an excellent but inflammable floor.

CHAPTER X.

RAILWAYS, ROADS, AND PAVEMENTS.

1. Lines of **land carriage** may be divided into **formation** and **permanent way.**

2. The **permanent way** rests on the formation and bears the traffic.

3. The **formation** includes earthwork, fences, drains, retaining walls, level crossings, bridges.

4. A **bridge** may be to cross another line of communication, to cross a river, or a valley in which case it is called a **viaduct.**

5. The permanent way may be a road, railway, or tramway.

6. A **tramway** is intermediate between a road and a railway; it consists of hollow or flat rails laid parallel on a road, to suit common wheels, or better still raised rails to fit hollow wheels. (No. 16.)

7. In laying out a **tramway** the first operation is to determine the **route, level,** and lay out the **centre line** with pegs, or whitewash if in a street. (2) Stack the materials in heaps of say twenty 18′ lengths, at suitable intervals, between footpath and roadway. (3) Ground is broken by a working party with crowbars to loosen the first paving stones, picks to get out the others, shovels to clear out gravel underneath; the track is thus cleared to the full width, say 8′ wide. (4) Two longitudinal trenches are now cut 1′ deep from the level of the surface of the road, and cross trenches every 6′ apart to the same depth.

8. The **sleepers** are laid first, and the longitudinals on them, wedged into **notches** $1\frac{1}{2}$ inch deep × $4\frac{1}{2}$ inches wide, splayed $\frac{1}{2}$ an inch inwards in opposite directions, and cut in the upper side of the sleepers, which are $6' 2'' \times 6'' \times 4\frac{3}{4}''$.

9. The outer sides of the **notches** are parallel to the direction of the rails at the proper gauged distance apart, allowing for the longitudinals to intervene say 5′ from outer edge to outer edge, the inner sides of the **notches** in the sleepers splay $\frac{1}{2}$ inch inwards one up and one down the line as above. (No. 8.)

10. The **longitudinals** are $6'' \times 3''$ in scantling, and any convenient length, say from 12′ to 18′ long, the shorter being used for curves.

11. The adjusting of the sleepers and ramming gravel under them is done simultaneously with the laying of the longitudinals to a gauge, and sawing off the ends to match each other in pairs, which is done on the spot by a carpenter and his assistants.

12. Holes to receive tie rods are then bored in the longitudinals at $\frac{1}{3}$ of their depth, say 2″ below their upper edge, and 3′ from each end; these tie rods may be of $\frac{3}{4}$-inch round iron with nut and head, and **washers** on the exterior side of each longitudinal to protect the wood when the tie rods are screwed up accurately to gauge.

13. On the longitudinals thus wedged and tied to gauge are laid the rails in lengths of 18′ or thereabouts, and a man with an accurate gauge rod in the grooves of the rails, assisted by another holding longitudinal and rail together by powerful forceps, nails the rail down to the longitudinal by nine nails, two at each joint opposite to each other nearly, and five alternate intermediate nails; the upper edge of the longitudinal is chamfered to receive the under side of the rails, and there is a fish piece 2″ wide, 6″ long, and $\frac{1}{4}''$ thick inserted under

the rails at each joint: the nails are large-headed fang bolts 3″ long.

14. Lastly, gravel is rammed well round and under all, the paving-stones are replaced, set with light mallets and firmly rammed home, remembering to give a good **cant** to the **outer rail** on curves.

15. The **ends** of the rails may fall anywhere, but the **ends** of the longitudinals **must** fall on sleepers, and it is better to cut them **in pairs** to save waste in subsequent adjustment, say 12′ or 18′ long.

16. The above is the construction of the Leipzig tramway; at Constantinople the rails are let into longitudinals laid **flat** instead of **on edge**, and this is manifestly better as it spreads the bearing surface on the ground, also a **raised rail** and **hollow wheel** collects less gravel.

17. The **selection of a line** for **a road** is influenced by statistical, commercial, and mechanical considerations. In an engineering point of view the object is to combine **economy** of **motive power** with economy of **prime cost** in construction.

18. The **objects** which answer the first desideratum are low summit levels, flat gradients, easy curves, and direct route.

19. As a rule, the **best point** for crossing a **ridge** is the **lowest pass**, but accessibility or facilities for cutting or tunnelling might in any instance alter the selection; the ridge should be crossed at **right angles.**

20. The **best** place for crossing a **valley** is at the **narrowest** part, where there is firm ground for the foundation of a viaduct: the deepest part should be crossed at **right angles.**

21. All **obstacles,** whether roads, rivers, or valleys, should, when possible, be crossed at **right angles**; the cost of square work being to the cost of skew work as $1 : \sec^2 \theta$, where θ is the angle of skew from the square.

22. A **line of road** running along the side of a

valley will be serpentine, winding round branch ridges and into branch valleys.

23. To obtain **easy gradients,** zigzags may be adopted; and even spirals alternately winding round over, and tunnelling through, the same ascending ridge.

24. Long reaches of **level** road should be avoided in a **cutting,** as they are difficult to drain.

25. The **ruling gradient** means the steepest general rate of inclination: the higher admissible, the cheaper the road will be; available motive power and waste of motive power are the two considerations which determine the ruling gradient as to its limits.

26. The **traction** of a carriage is to its weight,

On a stone pavement as	1 : 68
On a good macadamized road	1 : 49
Flint foundation road	1 : 34
On a gravel road	1 : 15
On a sandy road	1 : 7

27. Telford allows 1 in 30 as a maximum for the **ruling gradient** of a turnpike road. An ascent is much easier if taken in alternate slopes and levels than in one continuous rise, although the slopes must naturally be steeper in the former case.

28. A horse can drag with the force of 120 lbs. continuously and steadily at a walk; hence it can draw at a walk on a level stone road 120 lbs. × 34 = 4080 lbs., or 1 ton 16 cwt. 48 lbs. (No. 26.)

29. Roads are generally **constructed** by merely digging two trenches one on each side of the work in **level** ground, or on one side only of the work in **side-long** ground, and throwing (III., 45) the deblai on to the intended track, so as to slightly raise it; according to McAdam this is all that is necessary before metalling.

30. The **centre line** of the road, the sides of both slopes and trenches, are **pegged out with string** before ground is broken.

31. It is well to throw up **banks** well in **advance**, and let rain and weather consolidate them well before metalling.

32. In **marshy** ground the **road** should have a **foundation** made by digging a trench 3′ deep underneath it and filling the trench with clean sand or **gravel** as a base; or a layer of dry peat or fascines may be spread on the ground under the road.

33. If **fascines** are used as a foundation, they should be laid in two courses one across the other, altogether 18″ thick and picketed down. The fascines should be **constantly** wet, not alternately wet and dry, else they rapidly decay.

34. The ordinary **widths** in Britain for **roads** are fixed by law: **turnpike roads,** carriage way 30′, footway 5′, total 35′; **cross roads,** carriage way 20′, footway 5′. In some cases where land is of little or no value, roads are as much as 50′ carriage way, with two footways each 15′ wide; say total 80′.

35. As a rule for small **widths**, a road should be made in **multiples of 9′**, that being the clear space wanted for driving ordinary vehicles of the widest usual size; thus the narrowest parts of a road should be 9′, 18′, or 27′; for 1, 2, or 3 carriages to pass clear of each other.

36. The **middle of a road** should be 6″ **above** the sides, and this difference of level should be in the **formation**, the metalling being laid on **uniformly** thick.

37. Telford recommends an ellipse as the **form** for **cross section** of a **road** surface. Walker recommends two straight lines meeting in an angle at the centre of the road, as easier to lay down. (See No. 183.)

38. The **ditches** may be 2′ to 3′ deep and 3′ to 4′ wide at the top; if covered, they may be 6″ earthenware tubes, or built culverts of 12″ × 12″ section; in a town, the road drains discharge into **sewers.**

39. **Gutters,** or channels, run along each side of the

carriage way; they may be 3″ deep, 8″ to 12″ wide, paved, flagged, or brick on edge: and lead by branch gutters or tubes into the **side drains** or ditches, whose efficiency is all-important, as the goodness of the road depends entirely on the drainage.

40. **Mitre** drains are small underground tile drains or tubes, **diverging** obliquely V shape from the centre line of the roadway at intervals of 60 yards or so, and leading with a declivity of 1 in 100 into the side drains.

41. In **towns** the **gutters discharge** into **sewers** through gully holes provided with siphon traps or valves.

42. When a **road** is drained by an **open** ditch, the **fence** should be **between** the road and the ditch. Side excavations should have burgahs or gauge blocks left to show the height and facilitate measurement; these should be **removed** when the work is measured.

43. **Metalling** should be hard, tough, and durable: the best material is granite, trap rock, hard limestone, or flint gravel, which should be piled to **gauge,** 13″ high on the berm.

44. The best **size** and **shape** for **metalling** are 1·6 inch cubes, weighing 6 oz. each, for consolidation.

45. **Gravel,** besides being broken into angular pieces, should be **screened** through a riddle, to clear it of earth; metalling may be broken and gauged by machinery.

46. One layer of road **material** is spread with a shovel and rake, and consolidated by traffic before the next is laid down, this is repeated in three layers of 3″ each, or 9″ consolidated: but in many cases 6″ is sufficient thickness for the metalling. Good **consolidation** is of the very utmost importance.

47. Telford's **bottoming** consists of stone blocks 4″ cube to 7″ cube, set on the formation surface, which in this case has a rise of only 3″ from the sides to the centre; the 4″ cubes are laid at the sides, hand set, and

the 7″ cubes at the middle of the road; thus giving the full rise of 6″ from the sides to the centre for the metalling: small shivers of stone are driven into the interstices of the bottoming to bind it.

48. Whenever **new metal** is to be laid upon **old**, the surface must first be loosened with a pick to a depth of 1″, else the new will not bind.

49. Patchwork mending is called **darning**; for darning, finer broken metalling is used, the surface is loosened 1″ deep with a pick; the new metalling spread as deep as necessary, well watered and rammed.

50. **Sand** and **gravel** (called blinding) should **not** be spread over a new made road to make it easier; for they permanently keep the metal from binding.

51. **Mud** should be **scraped** off a road regularly.

52. Wheels of **small diameter** are the most destructive to a road: **broad wheels** run easier on soft roads than narrow wheels.

53. The **load** on a metal roadway should not exceed 1 ton on each wheel of 4″ width of tire without springs.

54. In France **steam rollers** are used weighing 10 tons.

55. **Stone paving** may have 6″ to 9″ of hydraulic concrete below it, or rubble masonry laid in hydraulic morter, or three 4″ courses of well-consolidated road metalling, or three 4″ courses of well-rammed gravel covered with 1″ of sand: for paving materials see Chapter IX., 66.

56. The best **size** for **paving stones** is, length across the roadway 9″ to 12″, breadth along the roadway 4″, depth 9″, they should be laid in **courses** lengthways **across** the roadway **breaking joint**; and inclined at an angle of 45° to the direction of the road.

57. **Paving stones** may **taper** slightly towards the **top** and have the open surface joints 1″ wide filled with

gravel or shivers in bituminous cement, but they must never taper downwards.

58. Granite cubes of 4″ edge have been used, laid on 1″ sand, on three 4″ layers of mixed gravel and chalk.

59. Paving stones are rammed with a 55-lb. beetle: they may when newly laid be **blinded** (No. 50) with sand and gravel 1½ inch deep.

60. Paving stones may be made **water-tight** by being laid in hydraulic morter or cement, or by being blinded with iron turnings mixed in the sand and gravel of Numbers (50, 59), or by being laid in bituminous cement (VI., 18), or **grouted** with hydraulic lime poured on in a semi-fluid state.

61. Rubble pavement consists of irregular stones set in a bed of sand or gravel; it is very **bad,** costly, and **inefficient.**

62. To **avoid** future **disturbance** of a well-built road in **laying pipes** for gas or water, or sewers, it is well to provide trenches at the side, under the outer edge of the foot pavement; with brick walls strengthened by cross arches, to stand the pressure from the roadway side. The outer wall of the side trench forms the back of a row of cellars under the foot pavement.

63. These **side trenches** may have cross walls arched as above, every 7′ or 8′; the side walls of the cellars of the adjoining houses act as buttresses to strengthen the cross walls of the side trench. The trench has been made 13′ deep from surface of footway to foundation of trench walls, 2′ 6″ wide inside: cross walls every 7′ apart, and the whole masonry 1 brick or 9″ thick: the 7′ lengths having a slight **bulge** or lateral curve to add to their strength; such a **side trench** could hold an oval sewer pipe 27″ × 18″, a 10″ water pipe, and a 10″ gas pipe.

64. Sewers are accessible through subterranean passages from trap doors in the foot pavement.

65. Footways of roads may be of gravel, engine ashes, broken slag (VIII., 15), burnt clay, &c., laid on from $2\frac{1}{2}$ to 4 inches thick, and rolled with a light roller from $\frac{1}{4}$ to $\frac{1}{2}$ a ton weight.

66. A **footway** may be 9″ above the bottom of the gutter and have a rise of 2″ from that side to the other: the roadway side of a footway may have a **curb** of 4″ to 6″ thick set on edge; or a slope of $1\frac{1}{2}$ to 1 down to the gutter.

67. In **streets, footways** have a foundation of concrete, broken stone, gravel, or sand, and are covered with **flagstones** from $1\frac{1}{2}$ to 4 inches thick.

68. The best **materials** for **flagging** are hornblende, slate, clay slate, gneiss, sandstone, and compact limestone.

69. Bituminous or **asphaltic pavements** are made of a layer ($1\frac{1}{2}$ inch thick for a carriage way and $\frac{3}{4}$ of an inch for a footway) of a mixture of road metal and bituminous morter (VI., 21) laid on hot in rectangular plots, the surface being then sprinkled with sand and the surplus swept off, the substance is left to cool.

70. Bituminous roadways may be made by breaking asphalt as for road metal, laying it on cold 2 inches deep, wetting all over with coal tar, and ramming with a 56-lb. **beetle.**

71. To **repair a bituminous** surface, dissolve one measure of bitumen (mineral tar) in three of pitch oil or resin oil; spread 10 oz. of the solution over each square yard of roadway, sprinkle over it 2 lbs. of powdered asphalt (bituminous limestone) (VI., 19), then sprinkle loose sand and sweep off the surplus.

72. Good **bituminous** pavement under constant traffic will wear out at the rate of one inch in 40 years.

73. Plank roads are formed by digging two parallel ditches 16′ apart in the clear, throwing the deblai (excavated earth) between them; half this width or 8′ is left, of earth sloping 6″ down to one ditch, the other half width or 8′ is **planked.**

74. The **planks** are 8′ long and 3″ thick, laid across longitudinal bearings 4′ 6″ apart from centre to centre, 10′ to 20′ long × 12″ broad × 4″ deep; the earth is well rammed under and about these longitudinals, and underneath their joints the ends rest upon blocks or short sleepers 3′ long × 12″ broad × 4″ deep.

75. The **planked** half width has alternate projections and recesses laterally on to the earthen half breadth of the roadway, say 3′ long × 3″ deep to furnish hold for the wheels of carriages to get on and off the track in passing each other.

76. A wooden pavement consists of rectangular or hexagonal prismatic blocks of wood 6″ deep, set on **end,** that is with the fibres vertical, upon a firm foundation of broken stone. The surface is slippery, and it is liable to rapid decay.

77. Cast-iron pavements are very dangerous to horses, but if cast as cells and filled with gravel they might answer.

78. Iron tramways now are generally made of tram rails, or oblong plates of **cast iron** 3′ or 4′ long × 8″ broad × 1½″ deep, slightly concave in the middle of their breadth, the joints resting on cast-iron plates 8″ × 8″ square, and also 1½″ thick.

79. On **railways** the coefficient of **resistance to traction** (No. 26) is made up of friction, and concussion of the air. The friction is independent of speed; the resistance of the air is insensible up to a speed of 10 miles an hour; above that it varies directly as the speed.

80. **Experiments** on **traction** are made in still weather on a dynamometer fixed between the engine and train, or else by letting the train come to rest of itself from a given speed, and observing the results as to inclination, time, and distance.

81. **Passengers** without baggage weigh 16 to the ton; **with** luggage, about 10 to the ton. A carriage to hold from 20 to 30 passengers weighs 6 tons, so the gross load is about three times the net load put into the train.

82. The **tractive** force of a **locomotive engine** is limited by the adhesion or **bite** of its wheels on the rails; the adhesion depends on the state of the rails, weather, &c., but may be assumed as $\frac{1}{7}$ of the load on the driving wheels, which load may be adjusted from $\frac{1}{3}$ to $\frac{1}{2}$ of the gross load by screwing up the springs.

83. The **load** on each **driving wheel** should not be allowed to exceed 5 tons, or 11,200 lbs., for the sake of the rails. The **bite** can, however, be indefinitely increased by the simple contrivance of laying a third or middle rail consisting of a cast-iron girder whose vertical web is compressed between the tires of two equal and opposite driving wheels capable of being screwed into closer proximity, and so taking a firmer compressive hold on the girder as wanted.

84. The **resistance** of a **passenger** train is about 6 lbs. per ton on the level; for a **goods** train it is stated at 9 lbs. per ton, or $\frac{1}{250}$ of the gross load. None of these rules are absolutely certain; they can only guide the engineer in the absence of local requirements.

85. In **determining** any incline or local **gradient** the engineer would consider the greatest load of a train, the least probable speed of ascent, the description of engine, and the ruling gradient (No. 25).

86. The best form of **brakes** act by the buffers on

all the wheels **at once**, holding them and causing them to **slide** instead of rolling.

87. Bogeys are pivoted frames on two or four wheels each, by which engine or carriages can be adapted for running round curves more easily.

88. On bogeys, **curves** of $3\frac{1}{2}$ chains, or 231 feet, may be travelled, but a shorter radius than 10 chains is not usual for railway curves.

89. On **curves** a **cant** is given to the outer rail to counteract the centrifugal tendency of the engine, and if v be the velocity in miles per hour at high speed, say 40; r the radius of the curve in feet; the **cant** of the outer rail = gauge $\times \dfrac{v^2}{15\,r}$. This applies equally to **tramways.**

90. In Britain the **gauges** for railways are:—

Narrow gauge	4′ 8½″;	cant of rails	$\left(\dfrac{6000}{r}\right)''$.
„ „	6′ 0″	„ „	$\left(\dfrac{7680}{r}\right)''$.
Irish gauge	5′ 3″	„ „	$\left(\dfrac{6720}{r}\right)''$.
Broad gauge	7′ 0″	„ „	$\left(\dfrac{8960}{r}\right)''$.

The **cant** of rails is in inches, and the letter r means the radius of the curve in feet.

91. One half of the **cant** is given by **raising** the outer rail, one half by **lowering** the inner rail.

92. In **traversing a curve** the wheels have not the same distance to go over, hence one would drag on the other were the **tires** not **tapered** or coned to rectify this, but the **tapering** causes oscillation in straight pieces of the line.

93. There are many ways of **setting out** railway **curves,** by sines or by arcs; the most common plan is as follows.

94. Curves and **cant** must be gradual; their object is to connect straight lines of different directions, and their change must be **elastic.** The **change** of cant between a straight portion and a curve is simply the cant of the curve; that between curves of the same or reverse direction of curvature is the difference or sum of their separate cants as calculated (No. 90).

95. First set out the **centre line** as for circular arcs with a stake at every chain length (No. 156); compute the cants and changes of cant (No. 90); multiply the greatest change of cant by 300; this product gives the **length of curve of adjustment** $= l$; calculate the **shifts** from the formula $s = \frac{l^2}{24\,r}$, and shift **each** stake of **each** curve inwards, that is, nearer to its own centre of curvature, by this distance s (straight lines are not to be shifted); this causes a **gap** b, between the adjacent ends of any pair of curves, equal to the sum or difference of the shifts.

96. To lay out the **curve of adjustment**, bisect the **gap** b, for its middle point or junction, and for its ends lay off its two half lengths, as calculated, along the shifted curves (No. 95); for intermediate points use rectangular co-ordinates measured from each end by the formula $y = \frac{4\,b\,x^3}{l^3}$.

97. Curves should be avoided on **inclines**; straight lines are not to be shifted to suit curves, the curve must be adjusted to the lines. Sometimes the gauge is increased on curves by half an inch, so that on the curves the wheels have 1″ play, or **clearance.**

98. The **breadth of formation** depends on the gauge, the number of tracks, the clear space left outside of them for projection of carriages and foot room, slopes of ballast, side drains, &c.

Say for a **single track**—

	Narrow Gauge.	Irish Gauge.	Broad Gauge.
	′ ″	′ ″	′ ″
Clear space outside of rail	4 0	4 0	4 0
Head of rail	0 2½	0 2½	0 2½
Gauge	4 8½	5 3	7 0
Head of rail	0 2½	0 2½	0 2½
Clear space outside of rail	4 0	4 0	4 0
Least breadth for top of ballast or span for over-bridges	13 1½	13 8	15 5
Slope of ballast, and benches, on embankments	3 10½ to 8 10½	4 4	9 2
Total breadth on top of embankments	17 0 to 22 0	18 0	24 7

For a **double track**—

	Narrow Gauge.	Irish Gauge.	Broad Gauge.
	′ ″	′ ″	′ ″
Clear space outside of rail	4 0	4 0	4 0
Head of rail	0 2½	0 2½	0 2½
Gauge	4 8½	5 3	7 0
Head of rail	0 2½	0 2½	0 2½
Six-foot way, between tracks	6 0	6 0	6 0
Head of rail	0 2½	0 2½	0 2½
Gauge	4 8½	5 3	7 0
Head of rail	0 2½	0 2½	0 2½
Clear space outside rails	4 0	4 0	4 0
Least breadth for top of ballast, or span of over-bridges	24 3	25 4	28 10
Slopes of ballast, and benches, on embankments	3 9 to 8 9	4 8	9 2
Total breadth on embankments ..	28 0 to 33 0	30 0	38 0

99. The **formation width** at the bottoms of **cuttings** may be from 0′ to 9′ wider than on top of embankments, to allow room for side drains.

100. The most common **breadths** of base for both cuttings and embankments on narrow-gauge lines are for single lines 18′, double lines 30′.

101. Over-bridges on narrow-gauge lines are usually, over a single track, 16′ to 18′ span; double track, 28′ to 30′ span; only **tunnels** are made of the minimum span shown in number 98.

102. The **formation level** is from 1′ 6″ to 2′ below the intended level of the rails, and has a transverse fall of 1 in 60 to run water off; cross drains from 7″ to 9″ deep and 3 to 5 yards apart, filled with broken stone, may be added when necessary.

103. Generally a **summit level** is the best position for a **station**, as it facilitates starting and stopping trains.

104. Power to **deviate laterally** from the sanctioned line is usually granted in Britain to 100 yards in country and 10 yards in towns. Power to deviate from the sanctioned level is usual up to 5′ in the country or 2′ in towns. Gradients may be altered 10′ per mile steeper than before, if less steep than 1 in 100; if 1 in 100, or steeper, they may be steepened 3′ per mile, but no greater excess: gradients may always be flattened up to 1 in 125.

105. The parts of a **road** whose **levels** are **altered** for the purpose of crossing a line are called the **approaches.**

106. The engineer must be prepared to show cause for adopting a **level crossing** in place of a **bridge,** and to prove that it is consistent with the public safety.

107. The **gradients of roads** are not to be altered to steeper gradients than—for a

Turnpike road ..	..	1 in 30	or less than 1 in 125.
Public road ..	..	1 in 20	
Private road ..	..	1 in 16	

For sizes of over and under **bridges**, their approaches, parapets, fences, &c., see (I., 98), (III., 164), (I., 104).

108. For the **mesne**, or average **inclination** between *a* and *b* on a line of road, add together all the rises + all the falls, and divide the total by the length *a b*.

109. The **fences** of **approaches** are not to be less than 3′ high; parapets of over-bridges not less than 4′ high: a good fence is made by running iron wire through living trees.

110. Pending **alterations** in a permanent line of land carriage, a **temporary** road must be provided by the railway.

111. Where a **line** of road has to be **crossed**, it is generally best to obtain the necessary **head room, both** by raising the approaches of the one line and lowering those of the other.

112. The **level** of **existing lines** is usually the best, as far as economy of construction goes: **level crossings** are cheaper than bridges.

113. The most formidable **impediment** to a railway is a canal crossing its line.

114. The **ballast** for a railway need not be so hard as for a carriage road, but should be sound and durable; it is commonly divided into **boxing**, or upper ballast, which is packed round the sleepers, chairs, and rails, to within $2\frac{1}{2}$ inches of the upper surface of the rails: and lower ballast 9″ to 1′ 6″ deep, say 6″ to 9″, + 9″ to 1′ 6″ = 1′ 3″ to 2′ 3″, for total depth of ballast.

115. In **selecting** an intended **route**, the engineer will be guided much by available sources of **ballast** in the

vicinity; the best ballast is 6-oz. road metalling (No. 43, 44); rotten and porous stone should be avoided.

116. Slag (VIII., 15), alum-work refuse, and engine ashes, are all good for metalling; burnt clay may be broken up and used; sand would answer where not liable to be washed away, but it is apt to get into the bearings of the machinery, and so do mischief.

117. Larch is the best wood for timber **sleepers**; they may be **creosoted** (V., 37) triangular or segmental section, base downwards, 9′ long × 10″ × 5″, laid 3′ apart from centre to centre; the sleepers are made by sawing a round 10″ log or a squared log diagonally in half.

118. Longitudinal bearers may be 12″ × 6″ to 14″ × 7″ deep, laid flat: if the bearing be continuous a $1\frac{1}{4}$-inch plank, 7″ or 8″ wide, should intervene between bearer and rail; otherwise **chairs** 3′ apart may be used: in either case cross ties should be fixed every 6 yards to keep the gauge; cross sleepers 7′ × 7″ × $3\frac{1}{2}$″ may be added, flat underneath the longitudinal bearers.

119. Cast-iron sleepers consist generally of two chairs supported on inverted bowls, and connected by a tie rod; the bowls have two holes in the top, so that ballast can be inserted and rammed from above: other forms have the chair as a **trough** furnished with spreading wings, or as a flat **plate** with the chair cast in the same piece above it.

120. Rails are **rolled** out of **fagots** of **puddled bar** iron (VIII., 38, 42): it is false economy to use inferior iron for the sake of cheapness in the rails. The **pile** before rolling is 7″ high, 6″ wide to 9″ wide by 10″ deep, and length such that $\frac{1}{4}$ of its ultimate weight may be allowed for waste.

121. The **ordinary length** of a **rail** is from 15′ to 21′, say 18′; and the weight, 70 lbs. to 100 lbs. per

yard; say 15 lbs. per yard of unsupported length for each ton of load on one driving wheel of the engine.

122. The **heads of rails** are $2\frac{1}{2}$ inches broad and are accurately laid to gauge, with a gauge rod furnished with shoulders. The sectional area of a rail in square inches is almost exactly one-tenth of the weight of one yard of its length in lbs.

123. It was originally intended to **reverse**, or **turn** the **rail** when worn out on one edge, but it is found unfit for further use.

124. **Rails** are held by **chairs** with chilled jaws, all made of **cast** iron, the rail being wedged in by a compressed oak key: but the keys are apt to start out, hence sliding chairs to fit exact to the rail without the wedges have been used; also **fish plates** with the eyeholes slightly elongated to allow for expansion and contraction.

125. The **weight** of an **ordinary chair** is equal to $1'$ run of rail, a **joint chair** where two ends of rails meet is equal to $1'\ 6''$ of rail.

126. If the ends of the rails are **fished** (No. 124), the **fish plates** may be $20''$ long, bolted through the rails by four bolts; in this case 2 ordinary chairs are used **close** to the fish plate instead of one joint chair.

127. The **fish plates** may be made of **angle iron**, and thus answer both as fish plates and chairs in one: these are called **bracket** fish joints.

128. The usual sections of a rail are I shaped, and called double T rail, or double-headed rail; the foot rail, the bridge rail, and the Barlow rail.

129. All **foot** rails *i. e.* furnished with broad flanges at the foot, may be either **bolted** down, or **fang bolts holding** the edges may **spike** the rail down. The joints may be held together by jaws tightened with cross bolts. **Foot rails** may be about $5''$ high and $7''$ breadth of foot.

130. Bridge rails are from 3″ to 5″ deep and from 7″ to 6″ breadth of base, they are either bolted to the sleepers like foot rails through slightly oblong holes, or held down by **fang bolts**; they **require** neither chairs nor (in the case of the Barlow rail) sleepers, but may rest direct on the ballast, the gauge being preserved by tie rods: in this case the depth would be 5″ or 6″ and breadth 12″; a saddle piece 3′ long fits underneath to connect the ends, and is bolted through.

131. All **bolt holes** in rails are made **oblong**, to allow for the expansion and contraction of the iron due to diversities of temperature.

132. The **weight** of **rails** per yard run is for horse railways 30 to 35 lbs. per yard.

Double T rail of No. 128	75 lbs.
Bridge rail, ordinary	82 „
Barlow rail	100 „

133. Rails are much the **steadier** for being supported at the **shoulders** on brackets, than at the base.

134. Neither **switches, points,** nor **cross rails** should occur at a **level crossing**, lest horses get injured.

135. Two lines of rails may be connected by **switches** (movable rails), **traverser,** or **turntable.**

136. The length of a **switch** may be 80′ from end to end, with a radius of 640′: they are to be **weighted** into such a position as to keep the **main line clear**, and can only be purposely and forcibly pulled to their other position.

137. A **traverser** is a platform which runs on transverse rails across the main line; it is used for shifting carriages, &c., from one line to the other when the tracks are **parallel.**

138. When the **tracks** are not parallel but radiating, a **turntable** is used. The turntable consists of the fol-

lowing parts: (1) a foundation of masonry or concrete; (2) a circular cast-iron base with a pivot in its centre, and a track for rollers round its circumference; (3) a set of conical rollers carried in a frame which turns about the pivot; (4) a deck or platform resting on the pivot at the centre and on the rollers at the circumference, carrying tracks of rails and provided with catches to fix the different positions.

139. It diminishes the friction of a **turntable** to throw the chief weight on the pivot. **Carriage** turntables may be 14′ diameter and carry two lines of rails at right angles. **Engine turntables** may be 40′ diameter and are worked round by wheels; they usually carry only one line of rails, and are useful for **reversing** engines as well as for changing direction to other radiating lines.

140. **Stations** should be well watered, well drained, and accessible easily both for passengers and goods.

141. **Passenger platforms** are 3′ above the level of the rails, the best construction is of strong flags resting on longitudinal walls, the ends should descend in **ramps** of 1 in 10, not in steps. The platform may be 20′ broad, or 40′ when used at both sides; the **roof** should **span** the **whole** station, at all events intermediate pillars should not be within 4′ of the tracks.

142. **Sheds** to be properly **ventilated.**

143. **Mile posts** are necessary by law every quarter of a mile.

144. **Gradient posts** are useful to the engine drivers wherever the inclination changes.

145. Where trains run at very short intervals, they must be worked on the **telegraph** system. It is compulsory on the railway company to construct **culverts** large enough to be accessible, to carry gas and water pipes under a railway. **Signals** should always be

weighted to fly to **danger** unless purposely pulled to **all clear.**

146. The **cost** of **a line** of land carriage should not exceed the **principal,** corresponding to the yearly amount made or saved by the road as **interest.**

147. The **best line** of road is a judicious combination between the **shortest, cheapest,** and most **level** lines: it is generally ascertainable at once within narrow limits from a good map.

148. The safest plan is to **follow** the course of a **stream or river,** as this secures moderate gradients and the lowest passes in the mountains: the more a road differs from such a direction the more steep and expensive will it be.

149. Ruling points through which a road **must** pass are laid down from the map and connected for a first approximation to the route; such points would be a mountain pass, a good site for a bridge over a river, or a large town whose traffic could not be neglected; the **exact position,** relative **height,** and **distance** of the **ruling points,** are next to be determined; from which the rise and fall between each, or **gradients,** are determined.

150. When the **gradient** is fixed, a clinometer and pot of whitewash will suffice to roughly mark out the line; then the track should be cleared, and plotted on paper.

151. A **valley** or **water-course line** is always far better than zigzags for a line of ascent into mountains.

152. In case of a sudden and **unforeseen obstacle,** which necessitates an alteration in the level of the road, it is best to recommence from the obstacle, alter the gradient, and work **back** till rejoining one's old trace.

153. The steps in **selecting a line** of road are followed up by a **personal reconnaissance,** in which **common**

sense and a practised eye are the only requirements, to see if there is any **self-evident** objection or improvement to the proposed line; then the section and survey are made, and the working drawings.

154. Levelling can be done at the rate of 3 miles to 6 miles per day; **surveying**, 3 miles per week, but much depends on the nature of the country: **bench marks** should be made wherever practicable, for future reference.

155. The **centre line** and **side widths** are next staked out, every 100 feet.

156. In setting out **curves**, the radius of curvature and change of direction or **angle to be turned** are known: it is found that a circle of 5730′ radius has a circumference of 36,000′; and since there are 360° in a circle, each degree of the circumference would be 100′ long; such a curve is called a 1° curve: if the radius were 2865′, the central angle subtended by a chord of 100′ is 2°, and the curve would be called a 2° curve, and so on. The **commencement** of a curve is generally marked P. C., for point of commencement; the **termination**, P. T. The best method of laying out the successive points in a curve depends on the geometrical theorem that the **change** of **direction**, or **deflection angle** between two equal chords, is equal to the angle at the centre subtended by either of them. The angles and chords are calculated in the form of Tables; sometimes instead of the **deflection angle** the **tangential angle**, which is half of it, is given (as in **Molesworth**).

157. A horse can drag—

3	times	as much	on the worst earthen road,
9	„	„	on a good macadamized road,
25	„	„	on a plank road,
33	„	„	on a stone trackway,
54	„	„	on a good railway,

as he can carry on his back.

158. The **load** for a pack bullock is 2 cwt., carried in India; the **load** for a pair of bullocks is 8 to 12 cwt., drawn. If the load drawn be represented by 1

The **traction** on a gravel road will be	.. .. ..	$\frac{1}{16}$	of the load
"	macadamized road, ruts and mud,	$\frac{1}{30}$	"
"	well-made pavement	$\frac{1}{62}$	"
"	plank road	$\frac{1}{100}$	"
"	best railways	$\frac{1}{280}$	"

159. The **resistance** caused by **gravity** in ascending inclines is as below: if on the level a horse can draw 1·00.

Gradient	0 in	100	a horse	can draw	1·00
"	1 "	100	"	"	0·90
"	1 "	50	"	"	0·81
"	1 "	45	"	"	0·76
"	1 "	40	"	"	0·72
"	1 "	30	"	"	0·64
"	1 "	25	"	"	0·52
"	1 "	20	"	"	0·40
"	1 "	10	"	"	0·25

160. One steep ascent in a line of otherwise level road requires a tractive force, which is **wasted** on all the rest of the line, or has to be specially provided for on the spot.

161. Only 12′ width in the middle of a road need be **macadamized** in most cases, the earthen sides being merely dressed.

162. Stone trackways, if used on important bridges for heavy vehicles, should be placed close to the curb of the footway on each side.

163. The **cost** of an **earthen road**, roughly, 20*l.* per mile in India, say from 10*l.* to 50*l.*; of a **macadamized road,** 200*l.* per mile.

164. The greatest **effect** commercially is obtained by the substitution of **earthen roads** for foot-tracks, or railways for earthen roads; other improvements do not

pay so well, though they may add greatly to the comfort and speed of travelling.

165. Sand added gradually in wet weather to a clay road, or **clay** added to a sand road, will make a very fair earthen road, where gravel or stone is unattainable.

166. In **black cotton soil,** thorough drainage of a road is of the first importance; the road should be embanked, say 3′ high, on plains, a coating of 6″ sand should **always** be laid on its surface, whether or not metalling is to succeed it; on a **sandy road** 6″ clay may be laid at least half width.

167. Road ditches must slope with the road's length not less than 1 in 125. (No. 104.) Good drainage alone will often turn a bad road into a good one.

168. Road ditches may be up to 3′, or in boggy soil 5′ to 10′ below the formation level; frequent cross drains should connect them, the ditches should be dug **evenly** and **continuously,** else it is impossible to measure the work, or distinguish old work with fresh-cut sides from new.

169. When **sand** is laid on a bad soil the surface should first be made to gauge the proper profile, then the sand or gravel laid on, well watered, and punned in two 3″ layers; lastly, the metalling, if any, is laid down.

170. Generally a **gauge ring** of 2½ inches diameter is used to gauge **metalling** for **construction** of a road; for the subsequent **repairs** a smaller gauge of 1¼ inch is used; the weights of such cubes of stone are 6 oz. and 3 oz. respectively.

171. One **labourer** should break 2 cubic yards **in a day.**

172. Metalling should be laid in 3″ layers, each well **consolidated** before the next is laid down; rollers may

be from 7000 lbs. to 19,000 lbs. weight, they are useless if too light; one inch of gravel may be spread over the new-laid metal, and the whole well watered and rolled with the lighter roller first, till the resistance decreases enough to allow the roller to be filled or **weighted** up to the heavier limit.

173. **Every part** of the road should be rolled from 40 **to 100 times**: metal for consolidation and repairs (170) should be piled to gauge, on opposite sides of the road, for convenience.

174. **One man** can **keep up** 3 miles of road by constant attendance and taking ruts **in time**. (No. 49.)

175. A cheap and ready method of bullock **cart tracks** is to dig out two parallel trenches, 18″ wide × 12″ deep, for the two wheels, and lay them with 4″ sand and 8″ good metal above it.

176. **Paving stones** (56) may be 9″ × 5½″ × 5½″, or, as in the "Euston Pavement," 4″ × 3″ × 4″ depth. The best foundation is sand or concrete, but gravel, pebbles, and broken stone are used; when concrete is used, 1″ of sand should intervene between it and the paving stones: when the road is not to be subsequently disturbed for pipes, &c., sand is **far** the best foundation.

177. **Sand** is **consolidated** when wet by a 40-lb. "punn," and the punning should reduce 12″ thickness to 8″; sand may overlie gravel or stone in foundation.

178. In a **plank road** the planks are spiked down, if 12″ wide or less, with **one** spike (6½″ long and ⅜″ square, chisel edges and broad heads, 5 to the lb.) at each end; chisel edge cuts across the grain. Such a plank road (No. 74) requires 13,200 cubic feet timber per mile and 2112 lbs. of iron spikes; 2640 cubic feet of the amount are for sleepers; the road will require renewal every 10 years.

179. To **improve a bog road**, 6″ of grass fascines and

6″ clay, covered by a layer of grass well kept up, may be used at a cost of Rs. 1 4 a., say 2*s.* 6*d.* English money, per 100 feet super.; but it only lasts one season.

180. A **width** of 20′ is quite enough for a **fair weather** or earthen **road.**

181. A road's **length** may be **increased,** to avoid an ascent of h feet, up to at least $20 \times h$ feet, with advantage.

182. In India the **considerations** are—1, drainage; 2, proximity to metal; 3, earthwork. In wide plains the **road** should be **curved** every 3 miles, and the *s* curve hidden by a clump of trees, with a well on one side, and a clump surrounding a police station on the other.

183. Road ditches should be **triangular** section, or nearly so. 1 in 24 is a proper slope from centre to sides of a road surface; the slope is laid down with a triangle and plumb line.

184. A **road** round a hill, or on **sidelong ground,** has one single cross slope of 1 in 24, to a ditch on its inner side, similarly laid off with a mason's level.

185. Mixing **chalk** or lime with **gravel** greatly improves it as a road **material.**

186. Bridges, beyond 150′ waterway on a first-class road,
100′ „ second-class road,
75′ „ third-class road,
require separate estimates.

187. In India a **traffic** observed at 50 carts per day costs 5*l.* to 10*l.* per mile in annual **repairs**; above 50 carts per day, 1 cubic yard of metal per cart per mile is calculated for wear and tear of surface.

188. Stone is never to be **broken** up for **metalling** on the road itself. A **gang** of 5 men should lift three yards or so all across the road, 3 of them picking and 2 breaking and **sprinkling** (not laying) the metal.

Stone may be broken by old men, women, or boys sitting.

189. Clay, chalk, sandstone, and freestone are **mischievous** materials. Old tracks should be carefully obliterated as soon as they begin to collect water.

190. The tools wanted for **such repairs** are

Strong **picks**, short handled	2	per gang.
Small **hammers**, 1 lb. weight in head, face the size of a shilling, well steeled	3	
10″ **rakes**, very strongly made, 2½″ iron teeth	2	
Light **shovels** with broad mouths	3	

191. The **price** of lifting a rough road, breaking the stones, forming, sprinkling, ramming, cleaning the watercourses, and finishing the road, **varies** from 1*d.* to 2*d.* per **yard** super., lifted 4″ deep. Say a road is 6 yards wide, and costs 2*d.* per yard super. to repair, this would give 88*l.* per running mile.

192. Roads should always, when practicable, be **made** and mended in **wet weather.**

193. On the **formation or bed** of a **railway** which is approximately levelled, say 20″ to 24″ below the intended surface of the rails, ballast is laid 18″ or 20″ deep; on this again the sleepers are laid: if the bearings be continuous the **longitudinal sleepers** may be 13″ wide × 6½″ deep, the cross sleepers 4″ × 6½″ deep, with their ends dovetailed into the sides of the longitudinals, at 12′ intervals.

194. Where stone is plentiful and easily accessible, Telford's **paved foundation** (No. 47) would be the best **bottom** for a road, otherwise Penfold's concrete foundation is preferable.

195. A **concrete foundation** has rendered roads most excellent which had previously baffled every attempt to make them solid. The process is as follows: The **hydraulic lime** is ground to powder, and 1 part of

lime mixed with 4 of gravel to form concrete; the lime is **then** slaked in contact with the gravel, and spread to a depth of 6″ over one-half breadth of the road; it is then (3 hours later) covered with 3″ of good hard broken stone, and left for five days, when a second 3″ layer of broken stone is spread on and rolled. The extreme excellence and durability of such a road is a set-off against its initial cost.

196. The **stone** used for **metalling** should be quite clean, and no **blinding** should be permitted (No. 50); but on the other hand, where stone is inaccessible, and the only available material is **gravel** consisting of **smooth round pebbles,** these should **not** be cleaned, as the binding material will be most useful; in fact, pebbles will never bind at all without it.

197. Chalk may be mixed with **gravel** to make it bind, otherwise chalk is very bad for a road material; **loam** and earth will also help a gravel road to **bind**; gravel not to exceed 6″ deep.

198. Great watchfulness is necessary on **first opening** a road to the public, else the road may be permanently ruined, if **ruts** are not immediately **raked in** and filled up; guards or **fenders** should also be placed to oblige vehicles to use every part of the road fairly.

CHAPTER XI.

TUNNELS, SHAFTS, AND GALLERIES.

1. For **ordinary borings** to ascertain the nature of ground, see Chapter (III., from No. 2).

2. As a general rule when a **cutting** is deeper than from 60′ to 75′, a **tunnel** is less expensive and should be substituted.

3. The **best** soil for **tunnelling** is **sound rock** not over hard; if very hard the work is more tedious but quite as easy. The **worst** soils for tunnelling are wet clay, quicksand, and mud; clay and shale are not quite so bad.

4. In **selecting a route** for a **tunnel** the following points should be considered: (1) nature of soil; (2) shortness of route; (3) accessibility by shafts.

5. All **curves** should be avoided in **tunnels**, especially such as shut out daylight from end to end.

6. The most **usual section** for a **tunnel** is arched with an invert, in fact **bell shaped**, though in stratified rock a pointed arch, and in flat strata a flat roof, have been used.

7. Common **dimensions** for a **tunnel** on a single line of railway are, height 20′, width 15′; for a double line height 24′, width 24′ to 30′; for a navigable canal, height 14′ to 30′; width 14′ to 30′.

8. The smallest **dimensions** for water conduits and drains, in which miners can work, are 4′ 6″ high × 3′ wide.

9. **Shafts** are of three kinds; (1) **trial** shafts, to ascertain the nature of the soil; (2) **working** shafts,

for access, removing deblai, &c., while a tunnel is in progress; (3) **permanent** shafts for light, admission of fresh air, and egress of foul air when the tunnel is completed.

10. Trial shafts are sunk in the line of the proposed tunnel; the usual dimensions are 6′ diameter if circular, or if a rectangular section be more adapted to the strata, 6′ × 4′.

11. Timbered shafts are rectangular in section. Those lined with brick or stone, called **steined** shafts, are circular.

12. Working shafts may be either timbered from 6′ to 9′ square, or **steined**, from 6′ to 9′ diameter; and their distance apart from 50 yards to 300 yards: to instance an extreme length, Mont Cenis tunnel is 8 miles long and entirely without shafts, the ridge being too high.

13. A range of **working shafts** may be either along the centre line of the tunnel, or parallel to it along one side and connected with it by **cross drifts.**

14. A **sump** is a waterpool excavated at the foot, when a **working shaft** is to be used for pumping, or bucketing the water out of a tunnel by windlass and buckets hung on trunnions to tip over on reaching the top.

15. Permanent shafts are generally working shafts of circular section with their steined sides (No. 11) resting on a brick or cast-iron curb in a circular orifice through the roof of the tunnel. The top is surrounded with a wall and covered with a grating.

16. In sound rock, **shafts,** or pits, are sunk by blasting and quarrying; the men should not be less than 50′ above **explosions.**

17. An **exhausting fan** or a furnace may be used to create a current up a shaft.

18. In soft earth a shaft **must** be **lined** with timber, or masonry or brickwork.

19. The parts of a timbered shaft frame are divided into **props** of round timber 9″ diameter; sills or horizontal bars 12″ × 12″, resting on the lower props and supporting upper props whose ends are merely abutted on to the sills between 4 **brobs** or 6″ nails; and cladding of boards, vertical **poling boards**, of 3″ deal.

20. The system of **underpinning** is the most generally useful in shaft sinking; it consists in supporting the superincumbent lining on a curb, and digging a smaller pit in the centre, placing a **block** at its base and raking props, in notches cut in the earth, slanting from the foot block to support the curb, then cutting away and removing the intervening earth below the curb: the shaft is thus sunk in steps or stages of about 6′ deep each.

21. In a **timbered shaft**, the upper end of the **raking props** would support the lowest **sills**, not a **curb**: when the central pit has been enlarged to the proper size, the shaft lining is thus continued; vertical poling boards with straw stuffed behind them if necessary to stop leaks, but in any case **tight** back to the earth, are first placed, with their tops behind the upper **sill** frame; next a lower sill frame is fitted together at their foot, then vertical props are fixed between the sill frames, the raking props are taken down, a fresh central pit is commenced, and so on.

22. If the shaft is **steined** the lining is built on a **curb** of elm or oak planks 3″ or 4″ thick with fished joints: the lining is a cylinder 9″ thick, in cement or hydraulic morter; a central pit is sunk, foot block and raking props placed as in (No. 20), the pit is enlarged to the proper size, a new curb laid at the bottom and the lining built up again upon it to give permanent support to the curb above while the raking props are

gradually removed as the brickwork replaces them: the curbs are left permanently embedded in the lining.

23. A **drum curb** is a curb made of timber or cast iron, with a sharp cylinder strengthened by brackets, below it, of the same diameter as the outside of the well ring.

24. In all cases a **shaft** is **commenced** by digging as deep as the earth will stand vertical: if a drum curb is to be used, it is then lowered in and built upon; when built up to the surface of the ground, the edge is undermined all round so that the whole well sinks together, and is built upon again at the top as it sinks, till it becomes **earth fast,** *i. e.* remains fixed by the friction of the sides: upon which an interior well of a smaller diameter may be sunk within the old ring from the bottom.

25. In using a **drum curb** great care is necessary to keep the sides vertical while the shaft is under construction.

26. A **working shaft** may be supported by its lowest curb resting on two strong parallel sills 15″ × 15″, each 10 feet longer than the intended span of the tunnel, inserted into small drifts at right angles to the direction of the tunnel, so as to lie 3′ or 4′ above the intended roof of the tunnel: these sills are let down the shaft in three pieces and scarfed together below.

27. A **working shaft** when, as above, in the centre line of the tunnel, may have its lining supported if the earth is too soft for the method described in No. 26, by the sills described above, each now in one piece, being laid across the mouth of the shaft rather closer together than the mouth of the shaft; the lower end being suspended from the two sills above by four wrought-iron suspending rods attached to a strong wooden frame below.

28. **Underground passages** are called galleries, mines, headings, or drifts.

29. A **centre heading** usually runs along the centre

line of the tunnel and **connects the** shafts either direct or by means of short **cross headings**. In soft material the principal **heading** may be at the **bottom** of the tunnel **and in the** centre; in hard material it may be **near the** top.

30. Galleries are driven in **solid rock** by blasting and quarrying: Mont Cenis was tunnelled by blasting and quarrying, the jumpers being driven by hydraulic power machinery: the rate of progress was for eight jumpers giving 200 blows per minute, 70 holes 3′ deep × 1½ inch diameter were driven horizontally in a day of six hours; and by blasting in these, 1 yard advance has been made in a day of 10 hours; the heading measured ten to thirteen feet breadth and 6′ 6″ to 10′ height.

31. Galleries or headings are lined with timber in soft soil. The lining consists of cap and ground sills 5″ × 6″, with side posts (or stanchions) also 5″ × 6″ tenoned into them; poling boards are placed behind or outside of the frames, and even under them if the soil is wet sand.

32. Old pits, mines, and tunnels are frequently found **full of water**; where this is likely, **precautionary** borings should be run to tap the water gradually.

33. The **cost and labour** of **mining** is usually from 5 to 20 times the cost of open-air excavation of the same quantity. This estimate roughly includes everything—blasting, lining, removing water, lights, temporary rails, wagons, &c.

34. A man takes about 3 days to a cubic yard of hard rock, or ¾ of a day for ordinary rock, in **underground** excavation.

35. The usual process in tunnelling is to run a **heading** along just under the centre of the roof of the tunnel, run side excavations slanting downwards to the

floor of the tunnel, leaving a wall in the middle to serve as a support for roof props if wanted, and for the centering of the arched roof, after the striking of which it can be removed.

36. All **hollows** between the lining of a tunnel and **the earth outside must be well filled with concrete.**

37. The cost of brickwork in tunnels is about double that in the open air (including lights). The proportions of the various items included in the cost are given in the Table :—

MATERIALS.		LABOUR.		MISCELLANEOUS.	
Bricks ..	30½	Mining (shafts, &c.)	3¼	Tunnel entrances.	
Cement ..	11	Mining (tunnelling)	15¾	Culverts.	
Timber ..	11½			Machinery.	
Ironwork ..	2½	Total	19	Buildings.	
Et ceteras ..	6½	Brickwork	12	Inspection, &c.	
Total ..	62		31		7

Material	62
Labour	31
Miscellaneous	7
	100

The total cost per yard of forward advance was 72*l.* The clear dimensions were, interior 24′ × 24′, and the thickness of lining 1′ 10½″ to 3′.

38. A tunnel front consists of **spandril walls** above the arch and wing walls at each side, like for a bridge. The end of a tunnel may have its arch secured against forward thrust by being tied back to a horseshoe-shaped curb of cast iron built into the masonry at a distance back from the end equal to about the height of the tunnel.

39. Tunnels may be **drained** by side drains like cuttings are; or, if provided with inverts, by a central culvert of which the invert is the floor.

40. A catchwater drain should protect the **front** of a tunnel from surface flooding.

41. Tunnelling in **mud** may be done by frames and poling boards, as in driving galleries. The Thames Tunnel, built by the elder Brunel, consists of two rows of arches, each 14′ in the clear width, enclosed in a rectangular block of masonry 37′ 6″ wide and 22′ high, the thickness of brickwork being 3′ at the sides, central wall 3′ 6″, crown of the arch 2′ 6″, crown of invert 2′ 6″, the whole mass being laid on 3″ elm planks.

42. A tunnel may be executed in **lengths** of 12′ or 15′, which are divided for convenience into **side lengths** on each side of a working shaft; **leading lengths** in prolongation of the tunnel from the side lengths; **junction lengths**, where two portions of the tunnel meet midway between two shafts; **shaft lengths** directly under the working shafts.

43. The first operation in **commencing a tunnel** is to drive a **gallery**, whose roof must be 1′ 6″ to 2′ above the intended top of the masonry.

44. The earth rests upon the **poling boards** (19, 41), supported upon horizontal longitudinal **bars** 10″ diameter, whose back ends lie on the top of the arch behind, or on props supported by the framework of the working shaft in the case of **side lengths** (42); the bars are kept apart by short struts, and their forward ends rest on vertical props, each on a foot block. When the excavation has descended to the level of the foot blocks, a strong sill 13″ × 13″, which has been let down in three lengths and scarfed together, is laid on the ground with its ends across the tunnel, let into the sides 2 feet at each end; on this sill vertical props are fixed supporting the **bars** at their forward ends, and the former props with their foot blocks are removed. Next the downward excavation is continued, slanting to the

rear, and struts two or three in number, 10″ × 10″, are placed to support the heavy ground **sill**, abutting against the finished masonry in the rear; the excavation is continued from the ground sill, slanting downwards to the front. Raking props are fixed on foot blocks, and fronted with poling boards. When the excavation has descended to these foot blocks another heavy **sill** is laid as above, props fixed upon it, the former props with their foot blocks removed, and so on.

45. The sides and bottom of the **excavation** are formed with great **accuracy** to **a mould.**

46. There are usually three ribs of iron to **centre** each length of roofing, covered by laggings with screws under each lagging. (V., 85.) The centres may be supported on cross sills resting on posts standing on the floor, and having their ends let into the side walls, the holes being built up after the centres are struck.

47. After the masonry of a tunnel for **one length** has been built, the top **bars** (44) may be pulled out and used again; those that will not come out must be built in or rammed round with earth; the earth must in all cases be tightly rammed round the brickwork.

48. The **centering** for a tunnel may consist of 3 or more ribs covered with laggings and braced together in lengths of 10′ or 12′. This is erected at one end of the tunnel, and when the arching is completed it is struck and moved on **nearly** its own length, only leaving 3″ underneath the finished arch to connect it with the prolongation.

49. The **centre line** of a **tunnel** is set out or **ranged** on the surface of the ground first, and then a row of shafts are sunk in convenient positions along the line.

50. Two **marks**, as far apart as possible, **in the centre line**, are necessary at the bottom of each shaft to

enable the true direction to be found by producing the straight line joining them.

51. The **marks** may consist of **nails** or spikes driven into the cross timbers. **Ranging curves** below ground may be done by means of a theodolite and candles, or lamps, instead of ranging poles (No. 5).

52. The **centre line** of the tunnel is ranged **below ground** by the following method: Having been ranged above ground (No. 49), two strong stakes are driven, say one 16′ behind the middle of the shaft and one 16′ in front of it, **both** on the centre line of the tunnel; **a spike** with an eye through its head is driven into the top of each stake, and the two eyes brought very exactly into the line required; a string is now stretched through the two eyes, and a couple of plumb lines dropped from this string to the bottom of the shaft will give the direction for the two **shaft lengths** (42).

53. The approximate direction can be fixed for the **heading** or **drift** by means of candles, each hung from the timber framing in a stirrup.

54. To set out the **levels** of a tunnel there must be a **bench mark** above ground, near the mouth of each shaft: when the shaft has been sunk and lined the level is transferred to a horseshoe-shaped staple driven into the lining of the shaft near the top, from which again it is easily transferred to the bottom by **a chain** or set of **rods**, spring-pinned together at their ends.

55. When the **tunnel** is not more than 300 yards long it is simply worked from each end towards the middle or junction point. Much judgment is required in choosing **place** and direction of the **borings** for mines so as to produce the entire effect within the intended tunnel and not to split or loosen the sides.

56. The best and indeed the only **new idea** on the subject of tunnelling (in which, as in all other branches

of engineering, writers seem to have borrowed from the same source, or from one another) is to be found detailed in Max Becker's 'Allgemeine Baukunde des Ingenieurs,' in an article headed "Die neue Tunnelbaumethode von Ingenieur Franz Rziha." It consists in doing away with woodwork altogether for the frame at all events of the centering, and substituting a shell of **iron frames** at intervals, covered by laggings to correspond with the intended inner surface of the masonry lining the tunnel; on these again are placed frames constituting a series of **rings** at the same intervals, and these rings, which support by wedges the ends of the poling boards (19, 41, 43), can have their shanks lengthened or shortened by screws, so as to admit of being eased off and removed separately with their superincumbent poling boards, and the voussoirs of the archwork inserted in their place. The same process applies to the **invert** as to the **arch.**

57. Herr Becker says, "Die Idee, welche bei dieser neuen Methode verfolgt wird, geht dahin, den hoelzernen Innbau ganz zu beseitigen und dafuer das weit dauerhaftere eisen zu verwenden. Ein eiserner Lehrbogen (centering) wird als haupt traeger aufgestellt. Auf demselben ist ein zweiter, aus kleinen Rahmen bestehender kranz ringsum gut befestigt. Dieser Apparat bildet zusammen den mehr erwaehnten Stollen rahmen. Will man auf dem Lehrbogen mauern, so nimmt man nach Maszgabe des Aufmauerung immer einen kleinen Rahmen jenes kranzes weg, fuegt statt dessen die steine ein, und bringt so ohne Holzbau das Gewölbe zum Schlusse."

58. The **most suitable size** for a **shaft** is not less (No. 12) than 6′ × 4′; and for a **gallery,** is that size in which the workmen can move with perfect **freedom,** though the first drifts may for the moment be smaller. The dimensions adopted in France, '**Aide memoire**

portatif à l'usage des officiers du Génie,' and on our own field-works at **Chatham**, are quoted below, and are well suited to lead to the ultimate dimensions of ordinary tunnels. (No. 7.)

59. Great gallery: clear height 6′ 6″ × width 7′ 0″; **capsill** 6″ × $8\frac{1}{2}$″; **stanchions** 6″ × 6″; **ground sill** 6″ × 3″. Frames 3′ to 4′ apart, poling boards or sheeting always of 2″ deal, any width, say 12″ wide; corresponding with the "galerie majeure" in France. The **time necessary** to advance one yard is thus made up: Fouille 4 h. 15 m.; pose d'un chassis 1 h. 0 m.; coffrage d'un intervalle 0 h. 45 m.; temps total 6 h. 0 m. Navvies would do it about five times more expeditiously.

CHAPTER XII.

PRICES AND RATES.

1. To give a **mere list** of prices, without further comment, could only mislead, as they vary so much in different localities: those given are as nearly as possible the **actual** rates for which work **is performed**.

2. The **prices and rates** depend (1) on the **amount** of various kinds of **work** which a common labourer or skilled artificer can turn out in a day, (2) on the pay the supply enables him to demand for his labour, (3) on the distance to which the manufactured article has to be conveyed.

3. The employment of **intermediate agents** between the engineer who designs a work and the labourers who make the bricks, quarry the stone, fell the timber, burn the lime, or actually construct it, necessitates a percentage or difference between the actual cost of the work and the amount of the estimate; this percentage is an equivalent for the saving which the contractor causes in arranging all the minor details so as to produce the results specified by the engineer without necessitating his constant supervision of such details.

4. Hence there is always a tendency on the part of labourers, artisans, and contractors to make the **rates as high** as possible and over-estimate all grounds of increase, while the interest of the purchaser in a money point of view is to **keep down the rates** to the lowest for which the work can be done.

5. In order that the engineer may do justice between

these two parties he must be quite certain what work is **worth** in his district, and it is the province of the superintending engineer to settle any reference for alteration in the schedule of rates, which should exclude all native names or measures. (IX., 63.)

6. As illustrations of **how a Schedule of Rates** is drawn up, the following examples are given:—

7. **Excavating foundations** in soft and hard gravel.

LABOUR.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Excavators	3	0 4 0	each	0 12 0
Women	3	0 2 6	"	0 7 6
MATERIALS.				
Baskets	2	0 0 8	"	0 1 4
Sundries	..	..	..	0 3 2
Total price or rate per 100 cub. ft. .. .. Rs.				1 8 0

8. **Masonry in foundations**, rubble stone and lime morter.

LABOUR.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Masons	2	0 10 0	each	1 4 0
Women	3	0 2 6	"	0 7 6
Masons' assistant	1	0 6 0	"	0 6 0
Water carrier	1	0 10 0	"	0 10 0
Grinding stone*	½	1 4 0	"	0 10 0
Labourers	4	0 4 0	"	1 0 0
Total for labour	..	..	..	4 5 6
MATERIAL.				
Rubble stone	100 c. ft.	3 0 0	100 c. ft.	3 0 0
Lime	18 c. ft.	15 0 0	40 c. ft.	6 12 0
Sand	40 c. ft.	1 4 0	40 c. ft.	1 4 0
Earthen pots	2	0 2 0	each	0 4 0
Baskets	2	0 0 8	"	0 1 4
Sundries	..	..	..	0 5 2
Total for material	..	..	..	11 10 6
Total rate per 100 cub. ft. .. .. Rs.				16 0 0

* The grinding stone includes the mill complete, with one man, 2 bullocks, trough, and woodwork, for grinding morter, besides the edge stone itself.

9. The rate for **interior of basement** up to the plinth will be the same, with the addition of extra labour in assistants and labourers; say, **interior of basement,** per 100 c. ft., Rs. 18.

10. The exterior of **basement** up to plinth is of **coursed rubble** masonry in lime, with tooled quoins, and the difference in rate is due to better class of stone, more careful setting, and 4 additional stonecutters at 12 a. each; say, **exterior of basement,** per 100 c. ft., Rs. 25.

11. Cut stone steps.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Mason	$\frac{1}{5}$	0	10	0	each	0	2	0
Labourer	$\frac{1}{5}$	0	4	0	„	0	0	10
Blacksmith	$\frac{1}{24}$	0	12	0	„	0	0	6
Labourer	$\frac{1}{5}$	0	6	0	„	0	1	2

MATERIAL.

Hewn stone 1 × 1 × 1	1	0	5	0	each	0	5	0
Charcoal	2 lbs.	0	0	6	2 lbs.	0	0	6
Lime	1 lb.	0	0	4	2 lbs.	0	0	2
Rubble masonry	$\frac{2}{5}$ c. ft.	24	0	0	100 c. ft.	0	1	7
Sundries	..		..		..	0	0	3
Total rate per ft. sup. .. .. Rs.						0	12	0

12. The **fractions,** $\frac{1}{5}$ of a mason, &c., mean that a man could do 5 times as much as a square foot, for ten annas, as far as **his** work is concerned. It is far better to state rates **per 100 feet** than **per foot,** because the very slightest difference in such small calculations amounts to a large sum when the total is dealt with.

13. There is an **arbitrary** distinction made between **labour** and **material.** None really exists, as the **cost** of material represents ultimately the **labour** of its production or manufacture and carriage.

14. **Archwork,** chisel-dressed stone.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Labour.				
Mason	¼	0 12 0	each	0 3 0
Stonecutter	¾	0 12 0	"	0 9 0
Labourer	½	0 6 0	"	0 3 0
Material.				
Undressed stone	4	0 2 6	foot	0 10 0
Lime mixture	..	..	..	0 3 0
Total rate per cub. ft.			Rs.	1 12 0

15. The Massāla, or mixture, includes, with lime—

Gool, goor, or Jhāgiri, = Sugar,
Hirda .. .. = Seed,
Tāg .. .. = Hemp,

which are mixed with morter. (No. 21.)

16. For **upper storey** add increase of labour and percentage on scaffolding; say, **archwork** chisel-dressed stone for **upper storey,** at Rs. 2 4 a. per cubic foot.

17. **Archwork,** burnt bricks and lime morter on ground floor.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Labour.				
Bricklayers	7	0 12 0	each	5 4 0
"	2	0 10 0	"	1 4 0
Labourers	8	0 4 0	"	2 0 0
Women	11	0 2 6	"	1 11 6
Water carriers	1½	0 10 0	"	0 15 0
Morter mill	1	1 4 0	"	1 4 0
Material.				
Lime	820 lbs.	15 0 0	1640 lbs.	7 8 0
Bricks	1300	13 0 0	1000	16 14 4
Earthen pots	2	0 2 0	each	0 4 0
Sand	40 c. ft.	1 4 0	40 c. ft.	1 4 0
Rafters	2	0 12 0	each	1 8 0
Baskets	2	0 0 8	"	0 1 4
Sundries	..	..	..	0 1 10
Total rate per 100 cub. ft.			Rs.	40 0 0

18. For extra labour and scaffolding, as in No. 16, add for upper storey Rs. 5 per cent.; say, brick archwork in upper storey, per 100 cubic feet, Rs. 45.

19. Opus insertum, or **random rubble** masonry, with cut jambs, quoins, &c.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Stonecutters	5	0	12	0	each	3	12	0
Masons..	5	0	12	0	,,	3	12	0
Blacksmith..	1	0	10	0	,,	0	10	0
Water carrier	$1\frac{1}{2}$	0	10	0	,,	0	15	0
Labourers	2	0	6	0	,,	0	12	0
,, ...	11	0	4	0	,,	2	12	0
Women	11	0	2	6	,,	1	11	6
Morter mill	$\frac{1}{2}$	1	4	0	,,	0	10	0

MATERIAL.

Rough quoins	29	0	3	0	each	5	7	0
Rubble stone	75 c. ft.	3	8	0	100 c. ft.	2	10	0
Lime	20 c. ft.	15	0	0	40 c. ft.	7	8	0
Scaffolding rafter	1	0	12	0	each	0	12	0
Charcoal	41 lbs.	1	4	0	82 lbs.	0	10	0
Sand	40 c. ft.	1	4	0	40 c. ft.	1	4	0
Coir rope	6 lbs.	0	2	8	2 lbs.	0	1	0
Sundries	..		..		..	0	10	6
Establishment	..		..		..	0	12	0
Total rate per 100 cub. ft. .. .. Rs.						35	0	0

20. Opus insertum, or **random rubble** masonry, with cut jambs, quoins, &c., for **upper storey**, add Rs. 5 per cent.; say, rate per 100 cubic feet, Rs. 40.

21. Lime plastering, 1″ thick.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Masons..	$2\frac{1}{2}$	0	12	0	each	1	14	0
Labourers	3	0	3	0	,,	0	9	0
Women	4	0	2	6	,,	0	10	0
Water carrier	$\frac{1}{4}$	0	10	0	,,	0	2	6

MATERIAL.

Lime	8 c. ft.	18	0	0	40 c. ft.	3	8	0
Sand	8 c. ft.	1	4	0	40 c. ft.	0	4	0
Goor (15)	2 lbs.	0	2	0	lb.	0	4	0
Hemp	2 lbs.	0	1	7	lb.	0	3	2
Pot	1	0	2	0	each	0	2	0
Baskets	2	0	0	8	,,	0	1	4
Rough rafters	$\frac{1}{2}$	0	12	0	,,	0	6	0
Total per 10′× 10′ = 100 ft. sup. .. .. Rs.						8	0	0

22. Plastering, roofing, &c., are commonly measured by the **square**, containing 100 feet super.

23. Lime plastering on upper storey. Rate per square of 100 feet super., Rs. 9.

24. Cut stone pavement.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Stonecutters	23	0	12	0	each	17	4	0
Masons..	$5\frac{1}{2}$	0	12	0	,,	4	2	0
,, ...	6	0	12	0	,,	4	8	0
Blacksmith	1	0	10	0	,,	0	10	0
Labourers	$2\frac{1}{2}$	0	6	0	,,	0	15	0
,, ...	8	0	4	0	,,	2	0	0
Women..	4	0	2	6	,,	0	10	0
Morter mill..	$\frac{1}{2}$	1	4	0	,,	0	10	0

MATERIAL.

Paving stone	117 ft. s.	0	3	0	ft. s.	21	15	0
Rubble stone	100 c. ft.	3	8	0	100 c. ft.	3	8	0
Lime	16 c. ft.	15	0	0	40 c. ft.	6	0	0
Sand	32 c. ft.	1	4	0	,,	1	0	0
Charcoal	$61\frac{1}{2}$ lbs.	1	4	0	82 lbs.	0	15	0
Pots	2	0	2	0	each	0	4	0
Basket	1	0	0	8	,,	0	0	8
Sundries	..		..		..	0	5	4
Total rate per square of 100 ft. sup. .. .. Rs.						65	0	0

25. Teak doors, half panelled, half glazed.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Carpenters	14	0	14	0	each	12	4	0
Labourers	14	0	4	0	,,	3	8	0
Sawyers' work	33 yds.	4	0	0	100 yds.	1	5	4

MATERIAL.

Stanchions 2 × 7′ 10″ × 5″ × 5″ =	2·72 c. ft.							
Lintel 1 × 6′ 4″ × 9″ × 3″ =	1·18 ,,							
Uprights 2 × 6′ 4″ × 5″ × 5″ =	2·19 ,,							
Plank 2 × $3\frac{1}{2}$″ × $1\frac{1}{2}$″ × $1\frac{1}{2}$″ =	1·31 ,,							
Sash bars 2 × 6′ × 1″ × 1″ =	0·08 ,,							
Supports 4 × 9″ × 2″ × 3″ =	0·12 ,,							
Inner frame 2 × 1′ 6″ × $3\frac{1}{2}$″ × $1\frac{1}{2}$″ =	1·31 ,,							
Total..	8·91 ,,							
Wastage at $\frac{1}{3}$ =	2·97 ,,							
Cub. ft.	11·88	3	0	0	cub. ft.	35	10	2
Iron hinges	24 lbs.	0	4	0	lb.	6	0	0
Double-pointed nails	1 lb.	0	2	0	,,	0	2	0
Panes of glass 12″ × 9″	12 lbs.	0	5	0	,,	3	12	0
Glazing panes	,,	0	1	0	,,	0	12	0
Pair of bolts	1	1	0	0	pair	1	0	0
Brass lock and handle	1	4	8	0	each	4	8	0
Hook and eye	1 pair	0	6	0	pair	0	6	0
Sundries	..		..		..	0	12	6
Size of door 7′ × 4′ = 28 sq. ft. cost.. .. .. Rs.						70	0	0
Which gives rate per ft. sup. .. .. Rs.						2	8	0

26. Glazed windows, 5′ × 3′.

LABOUR.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Carpenters	8	0 12 0	each	6 0 0
Labourers	4	0 4 0	"	1 0 0
Sawyers' work	18 yds.	4 0 0	100 yds.	0 11 6
MATERIAL.				
Jambs 2 × 5′ 10″ × 5″ × 5″ =	2·02 c. ft.			
Frame and capsill 2 × 5′ 4″ × 5″ × 5″ =	1·85			
Sash frames 1 × 32′ × 2½″ × 1″ =	0·65			
Sash bars 1 × 18′ × 1″ × 1″ =	0·12			
Supporting pieces 4 × 9″ × 2″ × 3″ =	0·12			
	4·66			
Add ¼ for waste	1·16			
Total cub. ft.	5·82	3 0 0	c. ft.	17 3 4
Hinges with screws	2 pair	0 7 0	pair	0 14 0
Panes of glass 11″ × 6½″	20	2 0 0	dozen	3 5 4
Bolts	1 pair	0 4 0	pair	0 4 0
Hooks and eyes	2	0 2 0	each	0 4 0
Handle	1	0 2 0	"	0 2 0
Sundries	..	..	..	0 3 10
Size of window 5′ × 3′ = 15′ super. Cost .. .. .. Rs.				30 0 0
Which gives rate per ft. sup. .. .. Rs.				2 0 0

27. Heavy timber for joists, lintels, side posts, &c., is taken out separately.

Cut teakwood, wrought and framed.

LABOUR.

	Number.	Rate. Rs. a. p.	Per	Rs. a. p.
Carpenter	1	0 12 0	each	0 12 0
Labourer	1	0 4 0	..	0 4 0
Sawyers' work	6 yds.	4 0 0	100 yds.	0 4 0
MATERIAL.				
Teakwood (and wastage)	1¼	3 0 0	c. ft.	3 12 0
Rate per cubic foot of cut teakwood, wrought and framed .. Rs.				5 0 0

27a. Dormitory floor, 87′ × 24′ = 2088 sq. ft. stone paving.

No. L. B. D. (′ ″ ″ ″)	Quantity.	Rate. Rs. a. p.	Per	Rs.
Girders, 11 × 26 5 × 12 × 16 =	388·66			
Joists, 32 × 88 0 × 3 × 7 =	410·66			
9″ from centre to centre.				
Wall plate, 22 × 5 0 × 8 × 4 =	24·4			
" 2 × 24 0 × 4 × 3 =	4·0			
Teakwood .. .. c. ft.	827·72	4 4 0	c. ft.	3519
Stone paving .. .. .. ft. sup.	2088	1 0 0	ft. sup.	2088
Total cost of 2088 super. feet .. .. Rs.				5607
Also 2088 : 100 :: 5607 : 268. Hence cost of 100 feet super. Rs.				268

As quoted in Schedule.

27b. Verandah floor, $52' \times 12' = 624$ ft. super. Joists, 9″ apart from centre to centre.

	No.	L.	D.	B.		
Joists	69 ×	13′ 6″ ×	8″ ×	3″	=	155·25
Wall plates,	2 ×	52′ 0″ ×	4″ ×	4″	=	11·55
		Total	.. .. ..			166·80 c. ft. of teakwood.

ABSTRACT.

	Rs.	a.	p.
167 cubic feet teakwood @ Rs. 4 4 a. c. ft.	709	12	0
624 feet super. stone slabs R. 1 ft. sup.	624	0	0
Total .. .. Rs.	1334	0	0

624 : 100 : : 1334 : Rs. 214.

Hence, 100 ft. sup. costs .. .. Rs. 214 0 0

As quoted in the Schedule.

27c. Fractions of rupees are not entered in an **Abstract**, the amounts being taken to the nearest rupee. Only in **calculating** rates are fractions taken into account.

27d. Terrace roof, 18′ × 14′. Teakwood wedge-shaped joists $\frac{2''+4''}{2} \times 10''$ deep, 5″ apart at base; say,

24 joists,	16′ × 3″ × 10″	=	80 c. ft.
2 wall plates,	18′ × 4″ × 3″	=	3 „
	Total c. ft., teakwood ..		83·00

CONCRETE.

Between joists,	24 × 14′ × 6″ × 10″ ..	=	140 c. ft.
Above joists,	1 × 18′ × 14′ × 3″ ..	=	63 „
	Total c. ft., concrete ..		203·00

PLASTER.

Terrace, 1 × 18′ × 14′ .. .. = 252 sq. ft.

ABSTRACT.

	Rs.	a.	p.
83 cubic feet teakwood at Rs. 4 8 a. per c. ft.	273	8	0
203 „ concrete at Rs. 10 per c. ft.	20	5	4
252 sq. ft. plaster, including ramming, at Rs. 12 per 100 sq. ft.	30	4	0
Cost of 252 ft. super. .. .. Rs.	424	0	0

252 : 100 :: 424 : 168.

	Rs.	a.	p.
Hence the rate for 100 ft. super. .. Rs.	168	0	0

As per Schedule.

27e. Details for **zinc spouts** 3″ in diameter for 100′ length.

LABOUR.

	Number.	Rate. Rs.	a.	p.	Per	Rs.	a.	p.
Blacksmiths	25	0	14	0	each	21	14	0
Hammermen	23	0	6	0	„	8	10	0
Bellows boys	23	0	4	0	„	5	12	0
Coolies	4	0	4	0	„	1	0	0

MATERIAL.

	Number.	Rs.	a.	p.	Per	Rs.	a.	p.
Sheet zinc	189 lbs.	30	0	0	112 lbs.	50	10	0
Tin	2	0	8	0	lb.	1	0	0
Charcoal	1 maund	1	4	0	maund	1	4	0
Muriatic acid	¼ lb.	1	0	0	lb.	0	4	0
Iron for fastening, at 2 lbs. per 3′ run	66 lbs.	1	0	0	12 lbs.	5	8	0
Painting spout	100 gaj	4	0	0	100	4	0	0
Sundries	..	..			..	0	2	0
Total for 100 running feet .. .. Rs.						100	0	0

100 : 10 :: 100 : 10.

	Rs.	a.	p.
Hence rate for 10 foot run .. .. Rs.	10	0	0

As per Schedule.

28. The published **rates of work** are rarely to be depended upon, as on comparison with practice they will be found to favour one party. One of the best obtainable differs by as much as 30% from observed practice in favour of the trade. At the same time it must be remembered that some persons will tender for contracts, to underbid others, at rates so low that it is difficult to conceive how the work can be executed at all for such prices, and quite certain that good workmanship and material are incompatible with profit to

the contractor, especially as there are often contract deductions up to 20 or 30% on the estimated amounts. It should also be remembered that rates are not by any means fixed quantities; very far from it; and in a large government contract a man might be able to offer terms which would be ruinous if demanded for trifling works.

29. English Rates.

		£	s.	d.
Excavation, throwing out, filling, and carting away from the premises	per cub. yd.	0	2	2
Concrete for foundations	„	0	6	6
Reduced brickwork in mixed cement, all stock bricks	per 306 cub. ft.	13	10	0
Reduced brickwork in morter, all stocks	„	11	10	0
Gauged archwork, best malms rubbed and set in putty	per ft. super.	0	2	4
Sash and door frames bedded, and pointed, either so much each, or	per yd.	0	0	$2\frac{1}{2}$
Making good brickwork to window and door sills	each so much, or yard	0	0	2
Hoop-iron bond, pitched and sanded, either by yard run, $2\frac{1}{4}d.$, or	per lb.	0	0	2
Cube fir, fixed, but not framed	per cub. ft.	0	2	6
Cube fir, framed in naked flooring, &c. ..	„	0	3	0
Inch deal rough fitted—one edge chamfered	per ft. run	0	0	1
Wrought iron in bolts, straps, &c., and screw bolts	per lb.	0	0	4
Sound tiling bedded in hair morter	per ft. super.	0	0	4
Cube oak, framed, up to 6″ × 6″, scantlings	per cub. ft.	0	6	8
„ „ „ 10′ × 8″ × 8″	„	0	7	0
Three-quarter inch deal boarding, edges shot and fitted complete	per 100 sq. ft.	1	1	6
Half-inch deal boarding, rough, edges shot,	per ft. super.	0	0	$3\frac{1}{4}$
Deal, rough, edges shot in gutter boards ..	„	0	0	$6\frac{1}{2}$
Deal hip and ridge rolls $2\frac{1}{2}$″ diameter ..	per ft. run	0	0	4
Wrought iron in ties	per lb.	0	0	3
Portland stone, including cartage and waste	per cub. ft.	0	3	9
„ if above 6′ long	„	0	4	3
Sawing, or half-plain work in Portland stone	per ft. super.	0	0	6
Plain work, including sawing and setting tooled Portland stone	„	0	1	0

30.

Portland stone, sunk work	per ft. super.	0	1	3
„ moulded work	„	0	1	10

		£	s.	d.
York paving, 2½″, laid in morter	per ft. super.	0	0	10
„ in slabs or hearths	„	0	1	4
„ in jambs or mantles rubbed and set in morter	„	0	1	9
Throating, in Portland stone	per ft. run	0	0	1
Rebate edge	„	0	0	3
Chamfered edge	„	0	0	2
Iron cramps, let in and run with lead complete	each	0	0	2
Notches to slabs or jambs	„	0	0	4
„ for tie beams	„	0	2	0
Plug holes, including lead complete	per pair	0	0	7
Mortise holes	each	0	0	2½
Duchess slates, Bangor, laid on boards with iron nails dipped in boiling oil ..	per 100 sq. ft.	1	6	6
Cast lead, hoisted and laid complete	per cwt.	1	6	0
Milled lead „ „	„	1	6	0
Cast-iron water pipes, fixed	per yd. run	0	4	3
„ „ unfixed, 2″ to 6″, at 10*d.* to 3*s.* 9*d.*	„			
„ water gutters, 3″ to 6″, at 8*d.* to 1*s.* 10*d.*	„			
„ shoes to water pipes	each	0	4	0
„ heads to ditto	„	0	5	0
Inch and a quarter deal, for flooring, rough, edges shot, rebated, and filleted	per ft. super.	0	0	6
Inch deal grounds, wrought, one side framed and grooved for door	„	0	0	8
One and a half inch **deal** jambs, two panels, square and flat, rebated both ends	„	0	1	1
One and a half inch deal board, four panels, square and flat	„	0	0	11
9″ cast iron, butt and screw	per pair	0	0	10
6″ best iron rim lock	each	0	3	9

31. Entrance Door.

		£	s.	d.
Cube fir, wrought, framed, rebated, filleted, and grooved	per cub. ft.	0	4	0
„ curved	„	0	5	10
„ double rebated and double beaded	„	0	4	0
1½″ **Deal**, grounded and framed	per ft. super.	0	1	6
„ curved	„	0	0	10
„ jamb lining	„	0	0	11
„ curved soffit	„	0	1	5
2½″ „ dooring	„	0	2	0

		£	s.	d.
2″ Deal semi-fanlight	per ft. super.	0	1	6
¾″ „ capping	per ft. run	0	0	2
„ „ bent in forming	„	0	0	3
12″ hinges, with 1½″ screws	per pair	0	2	0
9″ iron rim and screw bolt	each	0	8	0
8″ „ „	„	0	6	6
10″ „ „	„	0	9	6

32. Sash Frames.

		£	s.	d.
Deal cased frames, oaksunk sills, 1″ lining, brass pulleys for 2″ double-hung sashes, 7′ 3″ × 4′ 9″	per ft. super.	0	0	10
2″ Deal ovolo double-hung sashes, with best flax lines and iron weights	„	0	0	11
1¼″ „ wrought one side and framed	„	0	0	7
1¼″ „ „ tongued, chamfered, and beaded	„	0	0	9
1¼″ „ back and butt	„	0	0	10
½″ „ beaded, 1½″ wide	per ft. run	0	0	2
¾″ „ tongued	„	0	0	3

Plaster.

		£	s.	d.
Lath plaster, float, and set with putty and whitened	per sq. yd.	0	1	5
„ twice whitened	„	0	1	6
„ float and set, with gauged putty twice whitened — curved work	„	0	2	3
„ float and trowelled stucco ..	„	0	1	10
„ „ curved work	„	0	2	2
Plain plaster moulding, twice whitened ..	„	0	0	9
„ curved work	„	0	0	11

33. Stucco.

		£	s.	d.
Render and float, half cement, half sand, jointed and twice coloured	per yard	0	1	10
„ curved work	„	0	2	1
Plain moulding	per ft. super.	0	0	10

34. Painting.

		£	s.	d.
Three oils and flat white, one side	per yard	0	0	7
Four oils and flat drab	„	0	1	2
Cornices, &c., flatted drab	per ft. run	0	0	1½
Sashes painted, one side flatted	per yard	0	1	3

35. Glazing.

		£	s.	d.
Best Newcastle Crown glass in new sashes	per ft. super.	0	0	11
" " above 2′ square	"	0	1	0

36. Paperhanging.

		£	s.	d.
Old paper taken down, sizing and preparing the walls	per doz. yds.	0	0	9
Hanging new paper	per yd. run	0	0	1
Printed paper	per 8 pieces	0	2	0

One piece = 63 ft. super.

37. The following prices are called **Masters' prices**, and are calculated in favour of the trade, that is, they give a profit of 25 per cent. above the cost at which the work can ordinarily be done.

The **Indian rates** are neither invariable nor of universal application; they may, however, serve to give a very fair idea of what any work should cost.

38. MASTERS' PRICES.

		£	s.	d.
Bellhanger, day work	per hour	0	0	9½
Bricklayer, "	"	0	0	9½
Labourer	"	0	0	6
Bricklayer in fire work, ovens, &c.	"	0	0	10
Carpenter or joiner	"	0	0	9½
Labourer	"	0	0	6
Mason	"	0	0	9½
Labourer	"	0	0	6
Modeller	"	0	1	0
Paviour	"	0	0	9
Painter	"	0	0	9½
Plasterer	"	0	0	9½
Plumber	"	0	0	10
Polisher	"	0	0	7½
Slater	"	0	0	10
Zinc worker	"	0	0	10½
Navvy	"	0	0	7½
" if working in water	"	0	0	8
Plasterer's assistant	"	0	0	6
" hawk-boy	"	0	0	3
Slater's labourer	"	0	0	7
" boy	"	0	0	3½
Zinc worker's labourer	"	0	0	6½

39. When the work is in the **country** add 6*d.* per diem for each man's lodging, &c., besides paying railway or coach fare to and from.

40. Bricklayer.

		£	s.	d.
Brickwork in morter, all place bricks ..	per 306 cub. ft.	14	1	0
" " all stock bricks	"	16	9	0
" " all old bricks used again	"	5	10	0
If scaffolding is found by workmen, add ..	"	0	5	0
In gauged arches, camber, &c., the face and soffit are taken out as best malms set in putty	per ft. super.	0	3	0

41. Drains.

Small drains, two courses high, pantile bottom, brick flat top ..	per ft. run	0	0	10
" three courses high, 9″ wide, half-brick sides, paved bottom, arched top	"	0	1	6

If done in cement add one-fourth.

42. Wells.

To find the quantity of brickwork in a well, $\pi r^2 - \pi r_1^2$ = area of the ring, multiply this by the depth and reduce to standard brickwork of $1\frac{1}{2}$ brick thick. One foot super. of reduced brickwork takes 16 bricks, and, at 1*s.* 1d., costs to the rod ..	14	14	8

43. Digging.

Earthwork in ordinary soil, up to 6′ deep ..	per yd. cube	0	0	8
Digging, levelling, and ramming	"	0	0	10
Wheeling every 20 yards	"	0	0	2
Digging, filling, and carting up to $\frac{1}{2}$ mile ..	"	0	2	6

44. Well Sinking.

Up to 8′ deep, 4′ clear diameter, $\frac{1}{2}$ brick steining and arching in	per ft. deep	0	4	0
For every 6″ extra diameter, add	"	0	0	8

The bricks are to be charged extra, by delivered on work or by day work prices. (No. 55.)

45. Glazing.

Crown glass, squares 3′ to 4′, fourths	per ft. super.	0	0	6
" according to quality, up to best	"	0	1	0
Ground glass, 3′ to 4′ square	"	0	1	4

		£	s.	d.
Crown glass in new sashes 9″ to 1′ 6″ square	per ft. super.	0	0	3
„ „ up to best	„	0	0	7
Ground glass, 9″ to 1′ 6″ square	„	0	0	11
Polished plate glass, under 1′	„	0	1	10
„ „ „ 2′	„	0	2	4
„ „ 65′ to 70′ superficial ..	„	0	4	6
Coloured glass, according to colour (yellow)	„	0	2	2
„ up to green	„	0	2	10
„ deduct 6*d.* for second quality	„	0	1	6
„ up to	„	0	2	4

46. Masonry. In **measuring masonry** take each class of work separate; take throats, grooves, joggles, rebates, &c., by foot run; plugs, holes, cramps, mortises, &c., by number.

		£	s.	d.
Portland coping, 2½″ thick by 12″ wide, throated and set	per ft. run	0	3	0
Quarry worked 12″ weathered coping ..	„	0	1	6
„ window sills, 8″ × 3″ ..	„	0	1	10
Window sills, 8″ × 4″, sunk and throated ..	„	0	3	3
Add for every ½ inch extra thickness	„	0	0	8
Sawing stone or half-plain work	per ft. super.	0	0	8
Throating or chamfer	per ft. run	0	0	2
Curb, 6″ × 6″, including joints	„	0	3	3
Bath stone in blocks, cut, hoisted, and set ..	per ft. cube	0	2	10
Plain work in beds and joints, from 7*d.* to ..	per ft. super.	0	1	4
Granite hoisted and set	per ft. cube	0	6	6
Portland stone, cartage and waste	„	0	4	0
Yorkshire stone in block	„	0	3	9
2½ inch York paving	per ft. super.	0	0	10
6″ York landing	„	0	5	0
Stone paving 6″ thick	„	0	2	6

47. Painting.

Painting once in oil, and knotting	per sq. yd.	0	0	4
„ twice in oil, including stopping ..	„	0	0	7
For each additional coat	„	0	0	2½
Ladder work, that is, work requiring the use of a ladder, double price.				

48. Paperhanger.

Common paper, three colours or two blocks,	per piece*	0	1	0
Ditto, up to, according to pattern and quality,	„	0	2	0

* A piece of paper is 63 feet super.

		£	s.	d.
Pumicing, sizing, and preparing walls ..	per piece	0	0	6
Venetian blinds, any colour, over 16 sq. feet	per ft. super.	0	0	10
„ under 16 feet super.	each	0	13	0
Best white linen roller blinds, holland, with rack lines and tassels complete	per ft. super.	0	0	6
„ spring blinds, plated ends	„	0	0	10

49. House Bells.

Household bells hung complete, with cranks, copper wire, and labour	each	0	11	0
If with concealed wire and tubes	„	0	16	0
Trembling bells in mahogany case, complete, from 15s. to	„	2	0	0
Indicator: box of six indicators, polished mahogany and ebony	each indicator	0	15	0
Call buttons, fixed in apartments	each	0	4	0
Paper borders, mouldings, &c., ½″ wide ..	per yd. run	0	0	2
up to 2½″ wide, 2d.; black, 10d.; gold ..	„	0	2	10

Papering is also reckoned by the dozen yards run, of whatever width the strip may be.

50. Paving.

Common stocks, flat in sand	per yd. super.	0	2	11
„ „ on edge in sand	„	0	3	11
„ „ flat in morter	„	0	3	6
„ „ on edge in morter	„	0	4	6
„ „ flat in cement, add	„	0	0	7
„ „ on edge in cement, add .. to the rates for morter.	„	0	0	10

Making and levelling the ground is taken out as day work (No. 38).

One yard super. of paving requires 36 bricks flat, or 56 on edge; paving bricks, 32 bricks flat, or 84 on edge; 12-inch tiles 10 bricks flat, or 13 10-inch tiles, or 144 Dutch clinkers on edge.

51. Plasterer.

One coat rendering	per yd. sq.	0	0	6½
„ render and set	„	0	1	2
Lath and plaster	„	0	1	3
Lath only (single fir laths)	„	0	0	8½
Lath and plaster, float and set	„	0	1	10
Stucco on brick	„	0	1	4
Render and rough cast, on brick	„	0	1	0
„ „ floated	„	0	1	4

		£	s.	d.
Rough render in Roman cement and sand, mixed	per sq. yd.	0	1	6
„ on lath, with one coat of lime and hair	„	0	2	11
Plain face Portland cement	„	0	2	2
Lime whitewash, once	„	0	0	1½
„ „ twice	„	0	0	2
Wash stop and white, to new work	„	0	0	1½

52. Plumber.

Inch joints, including solder and labour ..	each	0	2	9
Strong 2″ pipes	per ft. run	0	3	0
„ 1″ „	„	0	1	3
4″ waste pipe, 7 lbs. to the foot	„	0	3	3
Common 2½″ lead pump complete	each	1	15	0
„ „ for deep wells ..	„	4	15	0
„ 4″ „ complete	„	3	5	0
„ „ for deep wells ..	„	7	15	0
Force pump, 2½″, complete	„	3	0	0
„ 4″, „	„	5	0	0
Hydraulic pump, 2″, complete	„	4	10	0
„ „ 4″, „	„	9	5	0
Centrifugal pumps, from 3″ diameter, to raise fifty gallons per minute, at 1-horse power for each 20′ of lift; price of pump ..	„	13	0	0
Up to ditto, 4′ 0″ diameter of pipe, to raise 25,000 gallons per minute, requiring 10-horse power to work the pump each foot of lift	„	650	0	0
Water-closet, pan and valve complete	„	2	0	0
Underhay's patent water-closet, with regulator valve, best quality blue basin	„	4	13	0
Blue printed basin	„	0	12	0
Stone ware closet pan and trap	„	0	7	0
Plain wash-hand basin, brass washer, and chain	„	0	5	6
Blue printed ditto	„	0	7	6
Cheap closet for cottages, complete, 12*s.* up to	„	0	16	0

53. Pointing.

Hoop-iron bond, 1½″ wide, No. 15, tarred and sanded	per yd. run	0	0	3
Pointing, including scaffolding, scraping, washing, and all	per ft. super.	0	0	6

		£	s.	d.
Brickwork, all stocks in Roman cement ..	per rod	18	10	0
reduced as quoted in books; the actual price is about	„	13	10	0
per rod of reduced brickwork = 306 cub. feet, being the actual rate at which a contractor could engage to get it done.				
Pantiling, laid dry, 10″ gauge	per square	1	6	0
Pointing outside and fillets, add	„	0	4	3
Hips and ridges	per ft. run	0	0	4
Valleys	„	0	0	5
Filleting	„	0	0	1½
„ in cement	„	0	0	2

54. Slating.

		£	s.	d.
Slating, per square of 10′ × 10′		1	10	0
„ „ with heavy slates		1	18	0
„ „ patent slates		2	4	0
Slate cisterns, 1″ thick, grooved and ready for fixing with bolts, &c.	per ft. super.	0	1	4
Fixing ditto, with oil, cement, bolts, brass-work, and cartage	„	0	0	4

To measure roofing, take the whole quantity covered, add the greatest width of eaves; run the hips and valleys, and multiply the length by 1′ for cutting and waste, and add 6″ for all cuttings to dormer lights, chimneys, angles, &c. Circular work is charged one-third extra.

		£	s.	d.
One square of slating weighs 5 to 6 cwt. Half-inch slab weighs 7 lbs. per foot super., or 1 ton to 1½ square = 15′ × 10′.				
A lady slate is 8″ × 1′ 4″, and 1000 ladies will do 4¾ squares. Each lady costs ..		0	0	4
A countess slate is 10″ × 2′; 1000 cover 7½ squares.				
A duchess slate is 1′ × 2′, and 1000 duchesses will do 10 squares. Each duchess costs		0	0	6
The price includes copper nails.				
Croggon's patent felt	per sq. ft.	0	0	1
„ „ 32″ wide	per yard	0	0	8
Galvanized iron roofing sheets, cheapest kind, weight, 10 oz.	per sq. ft.	0	0	3
Painted iron eaves' gutter, 3″ wide	per yd. run	0	0	6½
„ „ 5″ wide	„	0	1	0

		£	s.	d.
Zinc gutters, 2″ wide	per ft. run	0	0	3½
„ 4″ wide	„	0	0	5½
Iron manger rack and water trough, enamelled plate, brass plug and washer	each	3	12	6
„ „ „ „ „	up to	4	10	0
Manger rack and water trough, brass plug and washer	each	2	12	6
„ „ „ „ „	up to	3	10	0
Inch-deal mangers	per ft. super.	0	0	7

55. Materials. Bricklayer.

		£	s.	d.
Place bricks, in the field	per 1000	1	10	0
„ delivered on the work	per 100	0	4	6
Stock bricks, in the field	per 1000	1	18	0
„ delivered on the work	per 100	0	6	0
Add 5*s.* per rod of reduced brickwork for every 1*s.* per 1000 increase of price.				
Clay, delivered	per cub. yard	0	6	0
„ double load, = 2 cubic yards	„	0	12	6
Paving bricks, delivered	per 100	0	8	6
Pickings, in the field	per 1000	2	4	0
Cutters, or rubbers	„	3	0	0
Roman cement, delivered	per bushel	0	2	0
„ at the wharf	„	0	1	4
Portland cement, ditto	„	0	2	6

56. Any person who wishes honestly to ascertain what a piece of work will cost him, will appreciate the value of uniform denominations, such as feet or lbs., for space and weight measures respectively; he will find his investigations baffled by local tons of various weights, chaldrons, loads, heaped bushels, strike bushels, &c., &c., conducive only to confusion and fraud. A bushel here means a heaped bushel; and 22 strike bushels (of sand) = 18 bushels heaped. A **hundred** = 25 strike bushels (lime) = 18 bushels = 100 pecks (see No. 64), commonly known as a hundred of lime, equal to a volume of 36″ × 36″ × 37″. Uniformity of weights and measures should be enforced by law, as is done in Germany; any inconveniences are trifling when compared with the alternative impossibility of knowing what is meant by a cwt., bushel, load, or ton in various localities (see

IX., 63). Imperial measure should be **permissive** for one year, and **compulsory** after.

		£	s.	d.
Hair, 15s. per cwt.	per bushel	0	1	4
Sand .. .. per yard of 18 bushels	4s. 6d. to	0	6	6
Mastic, at the wharf	per bushel 5s. to	0	5	3
Chalk lime, at the wharf	per 100	0	9	6
" sent in or delivered	"	0	13	6
Stone lime, at the wharf	"	0	10	6
" delivered or sent in	"	0	16	0
Blue lias lime	per bushel	0	1	2
" " sent in	"	0	1	4
Pantiles, at the wharf	per 1000	3	12	0
" delivered	per 100	0	11	0
Plain tiles, at the wharf	per 1000	2	2	0
Hod of parget, or lime and hair	per hod	0	0	10
White lime	per pail	0	0	6

56a. Mason's.

		£	s.	d.
Concrete, 6 parts gravel to 1 ground stone lime, delivered	per cub. yard	0	7	6
Gravel, delivered, unscreened	"	0	6	0
Clay	"	0	6	0
Pebbles, delivered	per ton	0	15	0
Statuary marble	per cub. ft.	5	0	0
Veined marble	"	1	15	0
Black marble	"	2	0	0
Imitation marble, or enamelled slate slabs, 1″ thick ..	per ft. super. 2s. 9d. to	0	4	0
" " 2″ thick ..	" 4s. 6d. to	0	6	0
Stucco	per hod	0	1	7
Putty	"	0	1	9
Chalk lime for plastering	per bushel 9d. to	0	1	0
Thames sand	per bushel	0	0	4
Single size	per firkin	0	3	6

57. Painter.

		£	s.	d.
Brushes	each	0	0	3
Common colour	per lb.	0	0	6
Putty	"	0	0	2
Pots	each	0	0	8

58. Plasterer.

		£	s.	d.
Bundle of fir laths (= 500′ in length of fir laths, and 30 bundles to the load)	per bundle	0	2	0
Add for nails	"	0	0	4

59. Plumber.

		£	s.	d.
Milled lead	per cwt.	1	10	0
„ in gutters	„	1	14	0
Block tin	per lb.	0	1	6
Solder	„	0	1	0
Lead	„	0	0	4

Old lead, allow 4 lbs. per cwt. for exchange.

60. Smith.

6″ Barrelled bolt	each	0	1	6
Iron sash weights	per lb.	0	0	2
Cupboard lock, 3″	each	0	1	3
Tumblers	„	0	2	6
Wrought-iron chimney bars	per lb.	0	0	2½
Strong screw bolts and nuts	„	0	0	4
Hook and eye hinges	„	0	0	7

	lbs.	oz.
½″ square iron bar per ft. run, weighs	0	13½
½″ round „ „ „	0	10½
1″ square „ „ „	3	6
1″ round „ „ „	2	10
1½″ square „ „ „	7	8
1½″ round „ „ „	5	14

Wrought iron 1″ thick plates will average 40 lbs. per ft. super., and its price 12*s.* to 16*s.*	per ft. super.			
1″ wrought iron tube	per ft. run	0	0	7
Two inch „	„	0	1	8
Cast-iron grates or furnace bars	per cwt.	0	10	0
Wrought-iron ties, straps, &c., 1*d.* to 1¼*d.* ..	per lb.			
Brackets for shelves	each	0	0	9
Cloak pins	„	0	0	5

61. Carpenter.

Fixing cupboard locks and latches	„	0	0	9
Ash	per c. ft.	0	3	10
Elm or beech	„	0	3	2
Dantzig, Riga, or Memel fir	„	0	2	9
Oak	„	0	6	6
Mahogany, 1″ thick	per ft. super.	0	1	0
Oak „	„	0	0	8
Elm „	„	0	0	5
Fir cube in bond, plates, lintels, wood bricks	per cub. ft.	0	3	3
Rough fir, framed in naked flooring	„	0	3	9
Door and window frames	„	0	5	6

		£	s.	d.
Common shed roof, or lean-to, labour and nails only	per square	0	4	3
Cottage roof	„	0	5	3
If with purlins	„	0	6	6
Heavy trussed frame roofing	„	0	10	0
Hips and valleys	per ft. run	0	0	6
Rounded hip and ridge roll	„	0	0	4

Wall plates, lintels, &c., are charged as bond, in cube fir; timbers as fir framed, also gutter plates, binders, diagonals, struts, &c.

		£	s.	d.
Common ceiling joists notched on to plates	per square	0	4	9
Ground joists bedded not framed	„	0	4	0
Single framed floors trimmed to chimney and well holes	„	0	7	6
Girders, binding, bridging, and ceiling joists	„	0	19	0

Labour of hoisting large timbers is extra.

		£	s.	d.
Centering, where the materials are left to the employer, 1″ ribs and ¾″ deal boarding above	per square	2	3	0
For use and waste only of centerings	„	1	3	0
Striking and setting, if moved after the first erecting, allow ⅓rd.				
Rough boarding 1″ oak plank	per ft. super.	0	0	10
Inch deal, rough	per square	1	8	0

Allow 3″ waste for splays, hips, and angles.

		£	s.	d.
6 boards to a 3″ deal or ¾″ boarding for weather boarding	per square	0	19	0
Flooring and ceiling, ¾″ rough deal	„	1	7	0
Inch rough deal, edges shot	„	1	12	0
If ploughed and tongued or rebated and filleted, add	„	0	5	0

Allow 3″ for waste on splays, angles, &c.

62. Joiners.

		£	s.	d.
Inch-deal, rough, fixed or fitted	per ft. super.	0	0	4½
Three-inch rough deal, fixed	„	0	1	0
Sash frames, deal cased oak sunk sills, with brass cased pulleys, for 1½″ sashes, prepared to hang single	„	0	0	7
1½-inch deal ovolo sashes	„	0	0	7
Sashes and frames as above, with best flax lines and iron weights, single hung ..	„	0	1	3

To measure a window, take the height in the clear from head to sill and add 7″; width between the pulley stiles and add 8″.

		£	s.	d.
Doors, 1″ deal four panel square	per ft. super.	0	0	8½

		£	s.	d.
Doors, $1\frac{1}{2}''$ deal six panel square	per ft. super.	0	1	1
$2''$ doors four panel square	„	0	1	2
$2''$ doors six panel square	„	0	1	4
Sash doors, $1\frac{1}{2}''$ ovolo two panel square ..	„	0	1	1
Staircases, inch wrought clean deal steps, risers, and carriages	„	0	1	2
Add on the winders from where they arise ..	„	0	0	$1\frac{1}{2}$
If tongued, add for each edge	„	0	0	1
Inch rough deal steps, risers, and carriages	„	0	0	11

To measure stairs, take one flyer and riser the extreme breadth each, for a width, and multiply by the length; for winders take the area covered, adding always 1″ for nosings; and collect the risers separately. Widths are measured from top of one tread to top of the next to make good the part under the risers.

Hand rails and balusters deal moulded, $2\frac{1}{2}''$ wide and $2\frac{1}{2}''$ thick	per ft. run	0	1	1
Mouldings, half-inch common O G	„	0	0	$0\frac{3}{4}$
Half-inch quirked O G	„	0	0	1
Half-inch quirk ovolo and bead	„	0	0	$1\frac{1}{4}$

Inch moulding double the price of half-inch.

Inch beaded chair-rail, $3''$ wide	per ft. run	0	0	$2\frac{1}{2}$
Water trunks, $\frac{3}{4}''$ deal $4\frac{1}{2}''$ square	„	0	0	10
Inch „ $5''$ square inside	„	0	1	0
„ „ $6''$ square	„	0	1	1

63. Miscellaneous.

Battens are 7″ wide; deals 9″; planks 11″ wide.

Chimney pots, large size, fixed	each	0	6	6
Sawyers' work, per 100 ft. super.	per square	0	4	0
Burning clay into brick ballast (clay extra)	per c. yd.	0	2	6
Glue	per lb.	0	1	0
White lead	„	0	0	6
Pitch	„	0	0	3
Tar	per gallon	0	1	0
Single load of rubbish carted	per load	0	3	6
Cart, horse, and man per day	.. ..	0	12	0
Extra horse	.. ..	0	7	0
Baskets	each	0	1	6
Linseed oil	per gallon	0	5	0
Boiled „	„	0	5	6
Writing plain letters, per inch of height ..	each	0	0	$0\frac{1}{2}$
„ Egyptian „ „ ..	„	0	0	$0\frac{3}{4}$
Plain double shadowed or indented, add ..	„	0	0	$0\frac{3}{4}$

		£	s.	d.
Egyptian, shadowed or indented, add	each	0	0	1
Zinc, 2″ zinc pipes	per ft. run	0	0	5
„ 4″ „	„	0	0	11
„ 4″ stove pipes	„	0	1	1
„ 10″ flue	„	0	2	6
Zinc nails	per lb.	0	0	7
Perforated sheet zinc	per ft. super.	0	0	7
Malleable „	per lb.	0	0	7

64.

$11\frac{1}{3}$ cubic yards = 306 c. ft. = 1 rod standard, or 272 ft. super. of reduced brickwork.

36 bushels of cement + 36 bushels of sharp sand will do 1 rod of standard brickwork.

5000 place bricks, or 4750 stocks *laid dry* would do 1 rod.

4500 place bricks, or 4300 stocks laid in morter, would do 1 rod.

1 cu. ft. water = 6 gallons and 1 pint, and weighs $62\frac{1}{2}$ lbs.

1 square = $10' \times 10'$ = 100 ft. super.

500 ft. run of lath = 1 bundle. 30 bundles = 1 load.

1200 slates make 1000, or M.

25 strike bushels of lime = 100 pecks, called a hundred of lime.

65. INDIAN RATES.

		Rs.	a.	p.
Excavation of foundations	per 100 cub. ft.	1	8	0
Masonry, rubble, stone, and lime in ditto ..	„	16	0	0
Basement, interior up to plinth	„	18	0	0
„ exterior faced	„	25	0	0
Superstructure, rough stone and lime	„	21	0	0
„ in upper storey, standard barracks	„	28	0	0
Ashlar masonry	R. 1 4 a. per cub. ft., say	125	0	0
Tooled block in course masonry	per 100 cub. ft.	95	0	0
Cut stone, 6″ paving	per ft. super.	1	0	0
Brick and lime masonry (native burnt)	per 100 cub. ft.	32	8	0
Lime	per candy of 40 cub. ft.	15	0	0
„	according to quality, up to	30	0	0
Sand	per candy of 40 cub. ft.	1	4	0
„	qualities, up to	2	0	0
Moulmein teak in the rough	cub. ft.	2	15	0
„ wrought, framed, and put up		4	12	0

		Rs.	a.	p.
Indian teak		7	0	0
Doors, either panelled, or half-panelled half-glazed .. .. per foot super.,	R. 1 8a. to	2	8	0
Plank or batten doors .. .. ,,	10a. to	1	14	0
Windows glazed .. .. .. ,,	R. 1 8a. to	2	0	0
Single tiled roofs, small span, under 18′ ..	per square	40	0	0
Paving, 6″ rubble bed and chiselled stone ..	,,	60	0	0
above it	up to	62	8	0
Cement	per 100 cub. ft.	20	0	0
Plastering, 1 coat 1″ thick	per square, Rs. 10 to	8	8	0
Pointing per sq. ft., Rs.3 8a., according to height,	up to	4	4	0
Tiled roofing, bamboo battens ..	per square, Rs.35 to	45	0	0
Double tiled roofing all teak, span 24′ ..	per square	112	0	0
Teak battens and planking tongued, grooved, and varnished for verandah	,,	110	0	0
Flooring of trussed girders, teak joists 9″ from centre to centre, covered by 4″ stone slabs, span 24′ (27)	,,	268	0	0

66.

		Rs.	a.	p.
Flooring of verandahs without trussed girders	,,	212	0	0
Thatch roof, all included	per square, Rs.14 to	18	0	0
Pay of a smith .. .. Rs.15 8a. monthly,	or per day	0	10	0
,, carpenter Rs.12 4a. to Rs.25 monthly, or	,,	0	14	0
,, mason .. Rs.15 to Rs.20 monthly, or	,,	0	12	0
,, bricklayer Rs.15 to Rs.18 monthly, or	,,	0	10	0
,, strong cooley .. .. Rs.8 monthly, to	,,	0	6	0
,, common cooley	per day	0	4	0
,, woman	,,	0	2	6
,, boy, depends on size and use ..	,,	0	4	0
Stone slabs, 4″ thick, close jointed for roofs	per ft. super.	1	0	0
Concrete	per 100 cub. ft.	10	0	0
Plaster and ramming	per square	12	0	0
Basket	each	0	0	8
Water carrier	per day	0	10	0
Edge stone and mill complete for morter, with 1 pair of bullocks and a man ..	each	1	4	0
Rubble stone	per 100 cub. ft.	3	0	0
Earthen pots	each	0	2	0
Charcoal .. .. .. R. 1 4a. per maund	or per seer	0	0	6
Bricks	per 1000	13	0	0
Rafters	each	0	12	0
Rough quoins	,,	0	3	0
Coir	per seer	0	8	0

		Rs.	a.	p.
Paving stone	per ft. super.	0	3	0
Double pointed nails	per lb.	0	2	0
Iron hinges	„	0	4	0
Panes of glass, 12″ × 9″	..	0	5	0
Bolts	each	0	8	0
Brass lock and handle	„	4	8	0
Hook and eye	per pair	0	6	0

67.

		Rs.	a.	p.
Window bolts	per pair	0	4	0
Hooks and eyes	each	0	2	0
Handle	„	0	2	0
Sheet zinc	per cwt.	30	0	0
Tin	per lb.	0	8	0
Charcoal	per maund	1	4	0
Iron for fastenings	per 12 lbs.	1	0	0
Painting	per square, Rs.6 fine work, to	4	8	0
Archwork, brick and lime	per 100 cub. ft. Rs.40 to	35	0	0
Murram floor	per square	2	0	0
Doors barred for cells	per ft. super.	3	0	0
Windows barred and glazed	„	2	12	0
Fixed louvres barred	„	3	0	0
Colour and whitewashing	per square, 8a. to 7a. and	0	6	0
Deal boarded ceiling	per square	25	0	0
Double tiled roofing	per square, Rs.50, Rs.75	70	0	0
Teakwood railing	per ft. super. 12a.	0	10	0
Doors panelled above and fixed louvres below	„	2	0	0
Zinc ventilators	„	2	0	0
Teak woodwork, cut and fixed small scantlings	per cub. ft.	5	0	0
Privy seats	per sq. ft. 8a. to	1	0	0
Teak trap-doors in rear	each	1	8	0
Hammer-dressed masonry and rubble	per 100 cub. ft.	40	0	0
Chisel-dressed masonry	„	175	0	0
Archwork, chiselled face and brick backing	„	125	0	0
Ornamental jambs and mullions	per ft. super.	1	0	0
„ gratings under windows	„	4	0	0
Chisel-dressed cornice	per ft. run	2	0	0
„ corbel stones	each	1	8	0
Ornamental stone gurgoyles	„	40	0	0
Cut teak staircase	per ft. super.	3	8	0
„ flooring, including joists	„	1	4	0
„ ceiling, joists, and boards	„	0	8	0

68.

		Rs.	a.	p.
Cut teak cornice	per ft. run	0	4	0
Roofing, cut teak trusses, purlins, and rafters with cut teak planking and battens covered with corrugated iron sheeting	per square Rs.160 to	125	0	0
Hammer-dressed masonry	per 100 cub. ft.	80	0	0
Archwork, chisel dressed both sides	„	225	0	0
Ornamental iron finials	each at Rs.70 to	50	0	0
Uncoursed rubble masonry in lime ..	per 100 cub. ft.	18	0	0
Chisel-dressed steps	per square	75	0	0
Dwarf wall to steps	per ft. super.	1	0	0
Uncoursed masonry, brick jambs, &c. ..	per 100 cub. ft.	22	0	0
Murram filling	„	2	8	0
Chunam floor	per square	16	0	0
Deal boarded ceiling	„	25	0	0
Ceiling cloth	„	12	0	0
Glazed fanlights	per ft. super.	3	0	0
Fixed louvres, teakwood	per ft. super., R.1 to	2	0	0
Zinc eaves gutters	per ft. run, R.1 to	1	2	0
Zinc spouts or iron spout	per ft. run	1	0	0
Iron pipes, 3″ diameter	„	1	8	0
Cut stone choolas	each	1	0	0
Double tiled roofing to cook house	per square	65	0	0
Teak panel, cook-room door or privy door ..	per sq. ft.	2	8	0
Brick and chunam, for a privy	per 100 cub. ft.	33	0	0
Arches in brick and lime, or stone and chiselled pillars	„	40	0	0
Pan stones with channels (3′ × 1′ 6″)	each	4	0	0
Privy roof	per square	65	0	0
Semicircular arch heads	each	0	8	0

69. Petty repairs.

Yellow washing	per square	0	3	9
Pink washing	„	0	6	0
Surface repairs, earthen floors	„	0	9	0
„ chunam floors	„	2	8	0
Adjusting tiles	„	0	2	3
Cow-dunging floors	„	0	0	6
Oiling doors .. .. .. each, with cleaning 5 a.,	without	0	2	6
„ windows .. .. „ „ 5 a.	„	0	1	6
Renewing ceiling cloth	per square	6	0	0
Whitewashing ceiling cloth	„	0	5	6
Repairing ditto	„	0	3	0

		Rs.	a.	p.
Ceiling cloth taken down, repaired, re-hung, and whitewashed	per square	1	5	0
Whitewashing walls ..	per square, not for first time, 3 a.	0	2	6
New cornice of teakwood	per 10 ft. run	0	10	0
„ of junglewood	„	0	8	6
New bamboo joists	„	0	4	0
Repairing and refixing cornice	per 100 ft. run	0	12	0
New dammering (pitch) to woodwork ..	per square	2	4	0
Redammering ditto	„	2	0	0
Mineral browning	„	0	7	0
Painting woodwork	„	4	8	0
Repainting ditto	„	4	4	0
Pointing with hydraulic cement	„	1	0	0
Repairing stone in chunam	per 100 cub. ft.	4	8	0
Brickwork in chunam, repairs	„	6	8	0
Stone in mud	„	4	0	0
Brick and mud	„	4	12	0
Chunam plaster	per square	2	1	0
Mud plaster	per square, 12 a. to	0	8	0
Renewing chunam pointing	„ 10 a. to	0	12	0
Blue washing	per square	0	2	7
Cow-dunging walls	„	0	0	7
Renewing chunam plaster	„	2	15	0
Repairing fire-places with masonry	each	0	2	6
Scraping walls	per square	0	1	0
New mat frames, 20 sq. ft.	each	2	12	0

70.

Repairing mat frames, 20 sq. ft.	each	1	8	0
Remaking murram floor	per square	1	1	0
Wattle and dab walls renewed	„	1	12	0
Clay washing floors	„	0	0	8
New teakwood joists, rough slabs	each	1	2	0
„ junglewood ditto	„	0	10	6
Remaking chunam floors	per square	3	2	0
Repairing joists	each	0	11	6

71.

Flagged flooring in bath rooms, &c.	per square	40	0	0
Brick lining to flues (labour only 3 a.) ..	per ft. run, all	1	0	0
Shingles	at Rs.6 per 1000			
Shingle roofing, battens included	per square, Rs.17 split, to	22	0	0
Timber, deodar, up to 49″ section	per cub. ft.	1	6	0

		Rs.	a.	p.
Timber, deodar, up to 55 sq. in. section ..	per cub. ft.	1	11	0
„ „ above 55 sq. in. wrought, framed and put up	„	2	0	0
1½″ boarding to floors, including cornice ..	per ft. super.	0	4	0
Fire-grates, including sides	each	10	0	0
Jaffery, or trellis work	per ft. super., 3 a. to	0	4	0
Stairs	per ft. super.	2	0	0
Privy seats	8 a. per ft., or each Rs. 2 to	3	0	0
Iron venetians fixed	per ft. super.	10	0	0
Hoop-iron bond	per maund	12	0	0
Shelf complete, fixed on 4 brackets	per ft. super.	0	4	0
Table of 1½″ plank, framing and all complete	„	0	8	0
Weather boarding (excluding timbers at R. 1 6 a. per cub. ft.)	„	0	3	0
Pointing ..	per square, Rs.2 where lime is cheap, to	3	0	0
Brass hooks and staples	per seer, 12 a. to	3	0	0
Ironwork in grates	per seer	0	8	0
Coping, 3½″ thick	Rs.35 per square to per ft. super.	0	8	0
Dry walling	per 100 cub. ft. Rs.7 to	8	0	0

72.

		Rs.	a.	p.
Earthwork, hard soil	per 1000 cub. ft.	6	0	0
Blasting foundations in rock	„	30	0	0
1½″ flagging across drains	per ft. super.	0	6	0
2″ flags on 4″ concrete	„	0	8	0
Posts and rails, sawn scantlings	per ft. run, 10 a. to	0	8	0
Sheets of zinc, 7′ × 3′ = 21 sq. ft. (11 a. per ft. sup.)	each	8	8	0
Corrugated zinc sheets, 3′ × 3′ 6″	„	5	9	0
Lime plastering, where lime is cheap	per square, Rs.4 to	4	8	0
„ fine coat	„ Rs.5 to	6	0	0
Repairing railings	per ft. run	0	4	0
Chicks for church windows	per ft. super.	0	6	0
Repairing and painting church finials ..	each	3	8	0
Cloth for screens	per yd.	0	2	0
Rope cotton for lanyards, &c.	per seer, R. 1 to	1	4	0
Nails, according to size	per seer	0	8	0
Window ropes, each 3 a., 4 a.	each	0	6	0
Window pulley	„	0	8	0
Iron hooks 4 a. to 5 a.; iron pivots, each 6 a.	„			
Repairs to fire-places take out as masonry, at	per 100 cub. ft.	20	0	0
A grate weighs 6 seers to 13 seers	at per seer	0	8	0
Stone capping to chimneys	per ft. super.	0	8	0
Panes of glass fixed, if 10″ × 8″	each	0	5	0
„ „ „ 10″ × 12″	„	0	6	6

73.

		Rs.	a.	p.
Framing woodwork for tables, and such work	per ft. run	0	1	3
2″ planking (R.1 per plank 10′ long in the rough)	per ft. super.	0	8	0
1″ planking (8 a. per plank 10′ long in the rough)	„	0	4	0
Wooden door bar	each	0	8	0
Door-bar bolt	„	0	4	0
Latch and handle	each, R.1 8 a. to	3	0	0
Door bolt and screws (each 6 a., 8 a., 12 a.), or, per inch of length		0	1	0
Boarded floor, $1\frac{1}{2}''$ without timbers	per square	25	0	0
Accoutrement pegs	each, 1 a. to	0	3	0

74. Prices for Petty repairs, &c.

		Rs.	a.	p.
Repairing door bolt	each, 2 a.	0	6	0
Weather boarding, covers framing, and all at	per ft. super.	0	4	0
Hinge and screws, per inch of length	per inch run	0	1	0
Eaves boards	per ft. run	0	3	0
Iron window-rods	each	0	6	0
Brass door-handles, each cost Rs.3; fixing and repairing, at R.1 4 a.	total	4	4	0
Plain benches, no backs, rough make	each	2	1	7
Privy pans, hospital	each, Rs.2 12 a. to	1	3	3
String cots, thorough repair	each	4	0	0
„ new tapes to each	„	0	8	0
Barrack chairs or cane bottom	each, Rs.5 to	3	0	0
3″ boarding, unfixed	per ft. super.	1	0	0
Designation boards	each	2	8	0
Staples for door 1 a., for window	„	0	2	0

75.

		Rs.	a.	p.
Door, plain latch	„	0	4	0
Door catch (1 a.), hasp, and staple	„	0	6	0
Ladder up to 10 ft. long, 8 a. per ft. run, or each		5	0	0
Labour of fixing iron grates	„	1	8	0
Turning cots	„	1	6	0
3″ screws, Rs.3; 1″ screws, R.1; 2″ screws	per gross	2	0	0
Ceiling boards, falunda wood ..	per ft. super. 6 a. to	0	4	0
Ventilating pipes	per ft. run	1	8	0
Iron urinals, for hospitals Rs.10	each	3	0	0
Latrine pots, air-tight receptacles, Rs.12, ordinary	„	3	9	7
Posts and rails, rough	per ft. run	0	5	0
Reputtying panes of glass	each	0	1	6

		Rs.	a.	p.
Broken stone for floors	100 cub. ft.	3	0	0
Dismantling old masonry	„	1	0	0
Clothes' board, with pegs	each	1	8	0
Hearth stones, fixed	per ft. super.	0	8	0
76.				
Removing rubbish	per 100 cub. ft.	3	0	0
Stone steps, same as coping or flagging ..	per ft. sq.	0	8	0
Red clay filling same as murram ..	per 100 cub. ft.	2	0	0
Flooring of stone on edge in lime	„	30	0	0
Tooled masonry	per cub. ft.	1	8	0
Staple and door chain	each	0	6	0
Repairing a road 6′ wide with earth ..	per 100 ft. run	5	0	0
Ridge piece	per ft. run	0	2	6
Wooden trough, spouts, trunks, or gurgoyles	„	0	4	0
House drains	„	0	8	0
Masonry for privies or inferior parapets	per 100 cub. ft.	16	0	0
Wooden hooks for eaves gutters	each	0	3	0
Clearing drains by scraping	per 100 ft. run	0	4	0
Door cramp, 1 a.; door cleats	each	0	2	0
Cot, 2′ 6″ × 6′ 6″ × 2′ high, planked with wooden head rest	„	7	0	0
77.				
1″ iron rod, or flat iron	per maund	12	0	0
Putty	per seer	0	8	0
New arm or new leg to a chair	each	0	12	0
Recaning easy-chair bottom	„	3	0	0
„ common chair	„	1	8	0
To retape cots requires 6 seers each of nawar, at 1 a. 6 p. per seer, and 3 a. labour ..	„	0	12	0
New head-board to cot	„	0	6	0
Iron handle to a bath	„	1	0	0
Arm racks, Rs.12	„	13	0	0
Nails, 6″ long, Rs.15; 4″ long	per maund	16	0	0
Gunpowder, English, Rs.18; native	„	12	0	0
Lead	per seer	0	8	0
Kit boxes, repairing, R.1 12 a. each; new ..	each	6	4	0
Tape cots, Rs.8 each; string cots	„	7	0	0
Wooden gratings	per sq. ft.	0	7	0
Filter stand	each	4	0	0

78. School and hospital and barrack **furniture.**

School almyrahs	each	16	0	0
Metal basins (stands for them, R.1)	„	4	0	0

		Rs.	a.	p.
Black board and easel	each	4	0	0
Book-shelves, complete	„	8	0	0
Library book-case	„	12	0	0
Chopping blocks, large Rs.7; small	„	2	0	0
Wooden chairs	„	4	0	0
Mess cupboard	„	28	0	0
Dais chair for school, Rs.5; dais desk ..	„	10	0	0
15′ school desk, Rs.10; 10′ school desk ..	„	8	0	0
9′ long school desk, Rs.7; 4′ ditto	„	6	0	0
5′ form with back	„	7	0	0
5′ form without back	„	5	0	0
Jhamps, complete	per sq. ft.	0	3	0
Stool; footstool, 6 a.	each	1	8	0
Barrack lantern	„	4	0	0

79.

Solar lamp	„	7	0	0
Short ladders	per ft. run	0	6	0
Pointers, long, 4 a.; short	each	0	2	0
Iron padlock and key	„	1	8	0
Brass padlock and key	„	4	0	0
Box of pigeon-holes	„	12	0	0
Punkah fringes	per ft. super.	0	4	0
Cotton punkah ropes	per maund	35	0	0
Punkah canes	per dozen	1	10	0
Mess table, 10′ × 3′, or 10′ × 4′	each	20	0	0
Strong tables, 5′ × 2′	„	9	0	0
Cook-house tables	„	4	8	0
School table with two drawers	„	10	0	0
Teapoys or tressels, common	per sq. ft.	1	0	0

80. Furniture, &c.

Hospital almyrah	each	25	0	0
Broom, long-handled	„	1	8	0
„ short-handled	„	1	0	0
Hip bath	„	15	0	0
Foot bath	„	10	0	0
Slipper bath	„	12	0	0
Vapour bath	„	15	0	0
Easy chairs	„	8	0	0
Office chairs	„	5	0	0
Fine chicks	per ft. super.	0	1	6
Coarse „ bamboo	„	0	1	0
Sir cunda	„	0	1	4

		Rs.	a.	p.
Fracture cots	each	6	0	0
Ice boxes	,,	12	0	0
Pardah, complete	per sq. ft.	0	3	0
Trays dresser	each	4	0	0
Prescription tables	,,	6	0	0
Bedside table	,,	3	0	0
Dissection table	,,	15	0	0
Ventilating shafts	,,	60	0	0
Partitions in privies	per sq. ft.	0	8	0

81.

		Rs.	a.	p.
Ventilators, with tilting irons and venetians, perforated zinc sheets	per ft. super.	10	0	0
Ventilators, with fixed louvres and perforated zinc	,,	1	12	0
Sheet iron	per square	12	0	0
Iron grating	per ft. super.	1	12	0
Pile driving per lineal foot driven, all included	per ft. run	0	8	0
Concrete or beton	per 100 cub. ft.	8	0	0
Sinking pot wells up to 6′ diameter 10′ deep	per ft. depth	3	0	0
Maintenance of packa road, earthen repairs	per mile	200	0	0
Kunkur metalling, depending entirely on lead	per 100 cub. ft.	1	12	0
Stone broken for macadamizing	,,	3	0	0
Broken brick ballast	,,	2	12	0

82.

		Rs.	a.	p.
Timber, rough in the log	per cub. ft. from 8a. to	5	0	0
Two-bullock cart, to carry 12 maunds ..	per day	0	12	0
Four-bullock ,, ,, 25 ,, ..	,,	1	8	0
Laying and consolidating metal	per 100 cub. ft.	1	0	0
Turfing with sods, cut, and laid and watered	per square	1	0	0
Sowing with grass seeds and watering. ..	,,	0	4	0
Roofing, exclusive of timbers :—				
Flat pucka terrace on 1 course brick flat ..	,,	20	0	0
Thatched roof, 9″ thick	,,	18	0	0
Goodwyn's tiles in morter, on flat brick ..	,,	25	0	0
Common country tiling	,,	10	0	0
Flooring :—				
Terras, or terraced floor, on twice brick ..	,,	10	0	0
,, Brick or tile flat, on brick jelly ..	,,	10	0	0
,, Brick on edge, rubbers close jointed on khoa, laid to a levelling course of brick flat	,,	11	0	0

		Rs.	a.	p.
Panelled doors of local woods	per ft. super.	0	14	0

The rate given above at R.1 8a. includes timbers, but the measurements are to be taken the extreme height and width of the opening for a door or window.

83.

Cut stone masonry	per 100 c. ft.	40	0	0
Lining flues with bricks	per ft. run	1	0	0
Board flooring, 1¾″, ploughed and tongued ..	per ft. super.	0	5	0
Shingle roofing	„	0	3	6
Ceiling boarded, falunda wood	„	0	4	0
Ironwork in bars, hooks, &c.	per maund	28	0	0
Partitions of wood to privies	per ft. super.	0	8	0
Iron gratings, complete	„	1	12	0
Bair wood (karis), up to 7″ × 3″	per ft. run	0	1	3
For small scantlings, table legs, chairs, &c.	per ft. cube	2	0	0

84.

Ridge ventilation	per ft. run	2	0	0
		£	s.	d.
Excavation on an English Railway	per yard cube	0	0	10
„ over half a mile lead (extra) ..	„	0	0	3
Ballasting 18″ to 20″ deep, single broad gauge	per yard run	0	1	6
Total cost single broad gauge line	per mile	11,000	0	0
London and Epsom	„	35,000	0	0
Eastern Counties	„	46,350	0	0
London and Croydon	„	80,000	0	0
London and Blackwall	„	288,177	0	0
Laying iron	per chain	1	5	0
Navvy's pay	per day 3s. to	0	3	6
Timber for bridges, &c., depends on distance	per load	3	0	0

85.

		Rs.	a.	p.
Scindh roofing, hollow voussoirs measured flat	per square	8	0	0
2′ lengths of 6″ or 8″ earthenware pipe ..	each	0	3	0
Hollow tile voussoirs: making, 10a.; burning, 4a.	per 100	0	14	0

4 lbs. powder should be a liberal allowance for every 1000 cub. ft. in blasting; for quarrying, 3·7 lbs.

Raw iron for quarrying tools (native)	per maund	5	0	0
„ working the iron by hand forging	„	18	0	0
Quarrying 1 to 20 cub. ft. blocks Ashlar ..	per cub. ft.	0	2	0
„ 20 to 40 „ Ashlar ..	„	0	2	6
„ flags 2″ thick	per ft. super.	0	3	0

		Rs.	a.	p.
Rough dressing the Ashlàr	per ft. super.	0	1	0
Quarrying large rubble	per 100 c. ft.	3	14	0
„ small rubble	„	1	8	0

86.

		Rs.	a.	p.
Water-colour painting, stone colour	per square	0	9	10½
„ „ light yellow	„	0	8	0
„ „ buff colour	„	0	8	1
„ „ green	„	0	14	0
„ „ brown	„	7	15	9
„ „ blue	„	0	7	0
„ „ purple	„	5	7	0
„ „ pink	„	6	13	0
Finest whitewashing, 2 coats, work and material, laid on	„	0	8	0
Wooden fencing cut out of timber logs, and tarred over for railways	per 100 ft. run	30	0	0
„ „ „ „	per mile	3180	0	0
Iron fencing, bar iron with iron wire (in England, 206*l.*)	„	2060	0	0
Add for freight to Calcutta and insurance per mile, 30*l.*; inland carriage, 40*l.*				
Total cost per mile delivered	„	2760	0	0

CHAPTER XIII.

MISCELLANEOUS DETAILS IN BUILDING, &c.

1. The **site** for a public building must be approved by a **Board** consisting of an engineer officer, a medical officer, and an officer of the department for whose use the building is designed.

2. The excavation for foundation must be **measured as soon as finished**, that is, before the foundation has been commenced. Observe that the bottom is sound, level, and cut in level steps if necessary.

3. A round sum without further detail is generally named for **clearing the site**, preparatory to excavating the foundations, unless on very steep ground, where drawings and calculations showing how the result has been arrived at must be submitted.

4. In inspecting masonry, observe that the vertical bond is secured by **breaking joint**; that the headers are really what they pretend to be, **throughstones**; that the wall is not built in two halves, front and back half, with rubbish between; that the joints are neither too coarse nor wedge-shaped.

5. The safety of many structures depending greatly on the material with which they are **cemented**, it would be well to specify the minimum **tenacity** of the cement allowable, in place of prescribing the proportions of ingredients, with which it is next to impossible to secure compliance. Another advantage thus secured is the ease with which a practical test can be applied, instead of a troublesome quantitative and qualitative

chemical analysis of ingredients. The contractor should be given clearly to understand that if his cement falls short of the agreed strength, which can easily be determined by making some under the eye of the engineer, his work will be pulled down and rebuilt at the contractor's expense in a proper and workmanlike manner.

6. For a **light roof**, sheets of corrugated iron may be screwed down to laths nailed across common rafters resting on breastsummers mortised on to upright posts 10′ apart. The posts may be 6″ × 6″ × 10′ high, and rest on foot blocks of stone. The breastsummer may be 6″ × 6″ scantling; scarfed edgeways, not flatways, at the joints, which must fall on points of support; the rafters 2′ apart, scantlings according to span, and provided with collar or tie.

7. An **edging** should be made of **morter** round new masonry or brickwork to keep it wet whilst in course of construction, lest it dry too rapidly in hot climates. The rate of desiccation is very various. Blocks of concrete weighing 7½ tons dry in about 13 days in India, being wetted every day on the surface, and matting spread over them, to retard excessive evaporation.

8. The foundation may be uniform, but the **basement** will vary greatly in height on uneven ground, in order that the top of the basement may be level, whether or not it be surmounted by a string course 6″ high, projecting 3″ to the front, called the **plinth**, which may be from 1′ 6″ in inferior houses to 3′ minimum height above the ground for European dwellings.

9. The **thickness** of a **wall** depends upon its height and purpose as well as on the material of which it is constructed. 1′ 6″ should always be sufficient up to 20′ of height, however far apart the buttresses or cross walls may be placed which brace it. With first-rate material and workmanship 13″ would suffice for a

height of 35′. Generally the **basement** up to the plinth may be 6″ thicker than the wall above, and the **foundation** 6″ thicker than the **basement**, the increase being in offsets of 3″ on both sides of the wall.

10. It produces a very good effect to **line the openings** of a rubble masonry building with ashlar, mouldings, or even brickwork laid thus: 3 courses headers over 3 courses stretchers alternately, which gives an indented outline. If the bricks are painted complementary colour to the rest of the material they will still more add to the effect and be the more durable. In this manner window reveals, door jambs, and soffits, as well as chimneys, clerestory openings, and quoins, may be thrown into very effective relief.

11. A **door frame** consists of four pieces,—a capsill, a ground sill, and two side pieces or stanchions; say for a door 9′ 6″ × 4′ 6″ in the clear, the scantlings might be 4½″ × 4″ measured through and across the door frame. There is a chamfer all round the outside edge, and a rebate of 1½″ × 0¼″ all round the inside edge of the interior, to screw the hinges in and fit the door when closed. Each sill projects at least 6″ to 1′ at each end beyond where the stanchions are tenoned through it and pinned with trenails, so as to give returns which are built into the inside face of the wall as it progresses, the frame being held upright in its intended position by cross poles and lashing until the walls are built up around the frames. (No. 57.)

12. Wherever **stone steps** are to come, 7 or 8 **bond stones** must be left projecting from the wall face to bind the addition well to the previous work. The steps themselves are slabs of stone laid on rubble masonry, which may rest upon a platform of rubble masonry 6″ underground and 1′ out of the ground. A vertical groove forms a good junction of new work to old.

13. Gable ends are stepped down, and the purlin ends rest upon the steps in rough buildings, or they may have wall plates inserted in the masonry. Scantlings for roofs may be taken out from Col. Waddington's Tables or Col. Sankey's Tables direct for any span. The straps may be $1\frac{3}{4}''$ wide by $\frac{3}{16}''$ thick bolted through. The cleats of wood on which the purlins lean are nailed down to the principal rafters each by one nail $8\frac{1}{2}''$ long if the cleat is 3·3″ thick at the point nailed. (V., 57.)

14. If a **basement** be very high, a temporary ramp of rubble **stones** covered with **mud** may be used for wheeling, but mud must **not** be allowed to **touch** the masonry, else it will leave a stain.

15. In all masonry buildings upwards of 6′ high, **holes** are left, through which the horizontals for **scaffolding** are inserted; these holes are at vertical intervals of 5′ or 6′. The scaffolding may consist of bamboos or rough poles 4″ to 12″ diameter up to 30′ long; they are lashed together, and the lower butt ends let a few inches into the ground. Such a scaffolding is sufficient to bear a double-sheaved block worked by a five-ton winch for raising stones to the top of a clock tower.

16. The **dimensions** of public buildings being prescribed by regulations in accordance with approved **standard plans**, it would be superfluous to do more than give a general description, with cost, of a few, as a guide to future designs.

17. A **staff sergeant's quarters** might consist of—

1 main room, $16' \times 16' \times 16'$
1 bed room, $16' \times 10' \times 16'$
1 bath room, $10' \times 10' \times \frac{10' + 16'}{2}$
1 cook room, $12' \times 10' \times \frac{10' + 12'}{2}$
1 privy, $6' \times 6' \times 8'\ 6''$

18. Ventilation may be provided for by clerestory openings and by roof ventilation.

19. When **ridge ventilation** is adopted there should be an overlap of 4′ at least, in order to secure protection from rain driving in through the interval.

20. Such quarters as described in (No. 17), on a foundation 3′ deep built of rubble masonry, with basement 4′ 6″ high, of block in course topped with the usual chisel-dressed plinth, the verandah being 12′ in extreme width, paved with slabs set in cement on 6″ of rubble masonry, the superstructure being uncoursed rubble masonry, with tooled quoins, jambs, &c., for outer walls, and with brick jambs, &c., for inner walls. Roof double tiled. Teak breastsummers to verandah, and ornamental rails framed in lengths and fitted in between the posts. All doors having arch heads, external doors having fanlights revolving on a vertical axis, and internal doors having fixed louvres. The whole would cost at first-class prices Rs. 8000, or 800*l.*

21. The **plinth** or floor level of a cook room or privy may be 8″ to 1′ above the ground line.

22. Verandahs may vary from 5′ wide for native prisons to 10′ wide, or 12′ in first-class European buildings. 8′ is the best height from floor to breastsummer.

23. Windows may be either arched over entire, or a lintel of 3″ to 5″ timber may be used with a relieving arch over it.

24. Wood is ordinarily just built into the masonry as stone would be, but it is certainly better to ventilate the ends and keep them intact from morter.

25. In **plastering**, the first coat laid on is **rough**, and consists of sand and lime with a little hair. The tools used are trowel and board. The second coat is **straight**, and is floated with a flat board. The third is

a **fine** coat of putty or lime (VI., 56) without sand, and riddled through a sieve. Masonry should be well wetted before plaster is laid on, and the thickness should be limited to 1″. Each coat must be dry before the next is applied.

26. A complete **set** of **mouldings** forms an **architrave.** Each member is usually named, as quirk ovolo and bead, or quirk O G and bead, &c. The frame to be ornamented is always cut square, with a rebate if for panels, and the mouldings are planed separately, nailed on with **sprigs** or headless nails, the holes filled up with putty and the whole painted.

27. In a cold damp climate the walls are either **ducked,** or **grounded** with bond; that is, they either have blocks or wood bricks let into holes vertically above each other, at 20″ intervals; or they have horizontal bond pieces at 30″ vertical intervals. **Ducking** is the drier method, and should project $\frac{1}{2}$ inch inwards, to be clear of damp: on to these there are vertical pieces called **straps** nailed; they are 2″ × 2″ and 20″ apart horizontally; to these straps, the laths 2″ × $\frac{1}{4}$″ and about $\frac{1}{4}$″ or less apart are nailed horizontally and the plaster laid on the laths, and papered if wished.

28. A **fire-place** consists of two **jambs** and a **lintel**; the jambs may be either square or splayed; the depth of a jamb from front to back is called the **rumfording.**

29. Where there is plenty of room **stairs** should be made with good deep flyers and shallow risers, say flyers not less than 14″ deep, and risers, not steeper than $6\frac{1}{2}$ to 7 inches deep.

30. I find it useful to add the following on account of some ludicrous mistakes which have been made. The **seat** of a **water-closet** is pierced with an aperture whose edge should be chamfered, nosed, or moulded for comfort; the aperture should be a long narrow **oval**

with its length fore and aft, commencing **not** farther **back** than $2\frac{1}{2}$ to 3 inches from the front edge of the seat. I have seen one made with a circular aperture placed 10″ back from the edge! and the effect of such a mistake is as ridiculous as it is uncomfortable; the aperture may be $7\frac{1}{2}''$ to 10″ **wide**, and 12″ from front to back.

31. Rafters may be merely rough bamboos nailed on to the purlins and wall plate, but neatly dressed at the top to the ridge pole, and projecting 1′ 6″ beyond the external face of the wall below.

32. Staircases may be 3′ 6″ to 4′ 6″ for minor purposes, or 5′ 6″ to 7′ for main flights in large buildings, or even greater width in large ornamental public buildings. An easy form is to make two side flights each 5′ 6″ wide from below up to a landing say 18′ × 8′ or 10′, and one centre flight from the **landing** up to floor above say 7′ wide.

33.	Doors for large buildings may be	10′ 0″ × 6′ 0″
	„ ordinary „	7′ 6″ × 4′ 6″
	„ bath rooms	6′ 6″ × 3′ 6″
	„ privy	6′ 6″ × 3′ 0″
	„ cook room	7′ 0″ × 4′ 0″
	„ cells	7′ 0″ × 4′ 0″

34.	Windows for large buildings may be ..	10′ 0″ × 5′ 0″
	„ ordinary „	5′ 6″ × 3′ 6″
	„ bath rooms	2′ 0″ × 2′ 6″
	„ privy, ventilator	4′ 0″ × 4′ 0″
	„ cook room	4′ 0″ × 4′ 6″ to 4′ 0″ × 2′ 6″
	Clerestory openings ..	4′ 0″ × 2′ 6″ to 1′ 6″ × 4′ 0″

35. Thatchwork, like **tiling**, is commenced from below (155), working upwards, and each handful is sewn or tied down.

36. All **struts** have **tenons** at their ends, never **mortises**; they may fit entire into a hollowed seat or mortise, and have a tongue or bridle which further fits

into a groove. In determining the nature of a joint, the direction of the stress is the point to consider; the joint should deliver it at right angles.

37. A truss for a 40′ span may consist of a tie beam $5\frac{1}{2}'' \times 5\frac{1}{2}''$ scantling, in three lengths of teakwood, scarfed, fished, and keyed at the joints; the fish pieces are of iron $\frac{1}{4}$ inch thick on the upper and $\frac{3}{16}''$ thick on the lower surface of the tie; queen posts, straining pieces, and struts, diagonally braced, complete the framework.

38. A precisely **similar truss** may be introduced for **flooring**, by inverting the above frame and using a bar of round iron screwed up tight at the ends as a tie, passing under the queen posts and straining piece, which are now in compression instead of tension; all the **stresses** being **reversed** in the inverted position of the truss.

39. Ornamental eaves are made out of $1\frac{1}{2}$ inch plank of teak or other wood. They are first neatly traced in pencil, then roughly sawn or not, and afterwards chiselled off by the pencil lines; ornamental holes are simply bored with an auger; curves or elaborate devices are thus easily done on planks and nailed up into place subsequently.

40. For a gate, the wooden post is first fixed upright in the ground with a pin of wood or iron in its back, which is subsequently built into the masonry and acts as a tie to hold the post from leaning forwards; the pin should be at a height of $\frac{2}{3}$ of the height of the gate post; the masonry, of brick in clay, is next built up and plastered with chunam. The gate post may be either charred or tarred, and driven $\frac{1}{3}$ of its length into the ground, or placed in a hole 18″ square and held upright while broken stone is rammed well round about it.

41. Ornamentation in cornices, mouldings, &c.,

should not be too minute in proportion to its height or distance, that is, no member of a moulding such as a fillet, scotia, ovolo, bead, cyma recta, torus, or O G, should be less breadth than $\frac{1}{120}$ of its distance, if viewed from below or slanting; if viewed only in the fullest relief half this size, or $\frac{1}{240}$, will suffice; beyond these limits curves are lost in obscurity, and should it be necessary to group many members into an architrave of less breadth, it will be better to use corbelling in square fillets in place of curves. Where these proportions would give too heavy an architrave, mouldings would be out of place, and a **square collar** or **string course** should be substituted.

42. Floor joists may rest on blocks of stone or wood or on wooden templates built into the masonry (V., 99); the template might be 4″ by $1\frac{1}{2}$″ or 2″ thick, and is accurately levelled; the intervals between the ends of the joists are built up solid with masonry; the joists are braced laterally, to keep them firm on edge, by light vertical diagonal braces 2″ × 2″ scantling. The floor boards may be 1″ to $1\frac{1}{2}$″ according to the joist intervals; they should be ploughed and tongued, or rebated and filleted, to ensure close joints at the edges, and may be fastened down by two nails (V., 57) through each board where it crosses each joist. Laths are nailed (27) with sprigs (26) to the underneath side of the joists, and may be plastered for a **ceiling**; joists for a barrack, 7″ × 3″ at 1′ apart covered by $1\frac{1}{2}$″ boarding.

43. A chimney is built solid at both sides, the front is half a brick thick and the back 1 brick thick; the back is carried up solid, the front has a bar of angle iron or a stone slab with or without a relieving arch over it: the sides are corbelled in to 13″ × 10″ or so for the flue, and the chief point in all corbelling is to limit the projections to what can be well backed up, say

for brickwork $1\frac{1}{2}$ inch projection to each course (II., 73). The top of the chimney should be ornamented by **a collar**, of a depth and distance from the top suited to the height. (No. 41.)

44. Underneath the **sill** stone under a window, a 2″ hollow must be left in building, which is ultimately filled in with masonry inserted; the reason is that the superincumbent weight is all transferred to the jambs, and causes a settlement therefore at the sides of a window opening greater than under the window itself: this settlement is sufficient to **break** the slab unless the precaution of leaving a hollow under it be adopted. The skew backs and keystone of a window may be of stone, the remaining work being brick.

45. For a **roof** the ridge pole and hip and valley rafters are first fixed, the joints being tongued or shouldered and spiked together in a bunch; then the trusses which have been framed together on the ground are hoisted and put up, then the cleats are nailed on for the purlins to rest on; over the purlins come the common rafters, which rest on the purlins and wall plate, and are nailed to the ridge pole at their upper end, projecting 1′ 6″ beyond the wall at their lower end.

46. The **wall plate** may be placed on the middle of the wall, or flush with the outer face; the **purlins** should **project** 1′ 6″ beyond the external faces of the end walls. Wall plate may be $2'' \times 4''$ to $1'' \times 6''$.

47. There is an **offset** of 3″ all round the inside of the walls for a boarded floor, flush with the upper edge of the floor joists; on this a batten is laid for the floor boards. (No. 211.)

48. The **height** of a building means from floor to **tie** beam.

49. Solitary cells in order to give suitable proportions, and comply with existing regulations, may be

13′ × 10′ × 16′ high; walls 1′ 6″ thick, with one window 3′ × 4′, one door 4′ × 7′ 6″ opposite the window in the middle of the side wall; a sanitary arrangement is provided through an opening in the side wall 1′ 6″ × 1′ 6″ fitted with a teakwood frame 4″ × 3″ scantlings, so that the clear opening for the receptacle is 1′ × 1′. The teakwood frame is barred; $\frac{1}{2}$″ iron is sufficient for such bars to a solitary cell. Besides the windows, which are glazed and barred, there should be clerestory openings 2′ × 1′ to provide for efficient ventilation; if the cells are for European prisoners they should be double tiled, and a ceiling of $\frac{3}{4}$″ boarding, perforated with holes, should help, in connection with ridge ventilation, to keep the cell cool.

50. Wooden bond is largely introduced into masonry, and is very useful for fixing the interior fittings to, after the shell of the building is completed; such courses might be 4′ 6″ vertically apart.

51. In order to avoid placing **timber** in the **vicinity** of **fire-places** or chimneys, the joists or rafters which would have occupied the position are cut short at their nearest ends and tenoned into a strong cross joist or **trimmer**, whose ends again are similarly tenoned into the sides of the adjacent rafters or joists (V., 104) (XIII., 183), called **trimming joists.**

52. In order to **support a hearthstone** (228) **cleats** or laths of wood 1″ × 2″ are nailed against the inner sides of the floor joists bounding the fire-place; the slab rests on the cleats, and may be $3\frac{1}{2}$″ thick × 3′ 6″ × 1′ 7″.

53. Chimney arches and **window** arches may be of brick on **end,** therefore half a brick thick; thus, 16 bricks and keystone would suffice for an ordinary dwelling-house window; a second arch of the usual rise is turned over a flat arch to **relieve** it.

54. Doors and **windows** may be put up from the

inside of a building resting against a 3″ or 4″ edging on the outer face of the wall, 3″ deep, from which the jambs splay 9″ apart towards the inside.

55. Below the **chimney arch** and behind the window arch top (53) is a **slab** or lintel, say 6″ thick, and broad enough to be flush with the inner face of the masonry.

56. The portion **below a window**, from the floor up to the lower sill, is recessed from the inside to half thickness; the cheeks splay each 9″ or so, and there is a border half a brick thick projecting 3″ inwards on the external face of the wall for the sash frame to rest against.

57. The sash **frames** are made complete with pulleys, &c., plain outside and worked inside. Generally, all frames are very simple, merely plain square uprights and cross pieces the requisite strength, mouldings being nailed on afterwards with sprigs, and the holes covered with putty before painting. **Door frames,** instead of having **a rebate** cut, as described in (No. 11), may have **laths** nailed on all round the inside $1\frac{1}{2}''$ clear of the interior edge, the laths being $\frac{1}{4}''$ thick for the door to shut against.

58. An **ornamental cornice** may have its members cut out of stones laid in **courses** and resting on corbel stones, also moulded, and placed at intervals suited to their width.

59. In a **spiral staircase** each riser and tread (winder or flyer) may be 2″ thick, and let at its narrow end into a spiral centre piece, or **newel,** $2\frac{1}{2}''$ thick, cut in 2′ slant lengths; its broad end may rest on a string piece close to the wall. (V., 109.)

60. After the **purlins** have been truly adjusted perpendicular to the surface of the roof, the masonry of the **gable ends** is built up about them and over them, so as to be flush with the upper edges of the common rafters

or bamboos (umān), then the edge of the side walls is also built up to bury the wall plate and reach the upper edge of the common rafters, when it is all smoothly plastered over with chunam.

61. Where two **purlins** break **joint** they may be simply laid side by side, with their ends overlapping, on the same principal rafter, supported by the same cleat (13, 45). One common rafter overlies the purlins at each end **beyond** the end walls of the building, as the roof projects 1′ 6″ at the ends.

62. Stones are **carried** by ropes passed under them slung from poles; they are **hoisted** into position by the following arrangement: a cross pole is lashed to the scaffolding poles above the stone's intended position, and a double-sheaved block hung by a hook through a rope lashing from the cross pole, the uprights are held back by guy ropes, and a winch hauls the stone up from below. If the stones are dressed at the **quarry** instead of on the spot they should be **marked** before removal.

63. The **roofing** of a **verandah** may consist of—

(1) Verandah posts.
(2) Breastsummer.
(3) Principal rafters, built into the wall or resting on corbels at one end, and on the breastsummer at the other.
(4) Purlins.
(5) Common rafters.
(6) Bamboo battens.
(7) Matting.
(8) Single or double tiling.
(9) Eaves and ridges of chunam (borders).
(10) Possibly guttering, and dammer or pitch.

64. The **eaves boards** may be ornamental, and are nailed on at the ends of the common rafters.

65. If stone **steps** are to have **dwarf walls** at their sides, the platform (No. 12) must project 14″ at the sides of the steps to allow a 1′ wall being built

upon it: such a wall should be coped with stone or plaster.

66. Balusters to a verandah may be rectangular frames, having a top rail 4″ × 3″ rounded above, bottom rail and stanchions at each end; the under side of the top rail and upper side of the bottom rail have mortises cut in them at distances of 4″ to 6″ for the ends of the upright bars, which might be 1″ square section for a 3′ baluster; the bottom rail is an inch or two clear of the floor and the stanchions rest in ½″ deep recesses cut in the floor to receive their lower ends; the balusters are nailed by two 5″ nails to each verandah post.

67. Whenever a **frame** is put together it is usual to mortise the ends of the upper and lower cross pieces on to tenons cut at the ends of the uprights, which pass **right through** the mortise holes and are planed off on the outside; these tenons are cut small for the holes they are to fit and are wedged tight afterwards from the outside, and pinned with wooden pins or **trenails** (V., 114); similarly the intermediate cross pieces are tenoned through mortise holes cut in the side pieces or uprights, wedged tight, and pinned.

68. Panels are **separately** made and placed against a **rebate** or edging in the frame, where they are secured by moulding nailed on behind them (26); just as a pane of glass is secured in a frame of sash bars by the putty placed behind it.

69. Doors are commonly made half panelled and half glazed, the cheeks splay slightly apart inwards and the interior edge may have a plaster beading around it.

70. A **fanlight** frame may be in three pieces, with the ends strongly mortised and tenoned into each other, and pinned with wooden pins, each piece 4″ × 2½″ scantling; it is placed **by** the centering, just on its in-

side (V., 102) while the voussoirs are laid on; in India the top is lashed down to the horizontal bar in order to prevent warping, while exposed to the sun.

71. The process in fixing the **door frame,** is to carry up the walls to the level of the upper surface of the door frame (No. 11), whose returns are built into the masonry and mark the spring of the arch; then the **fan-light frames** (70) and centerings are placed and adjusted, and the walls left at this level height all round for eight days to settle before the arching is proceeded with.

72. The **rebate** of the **fanlight** is made to suit the way it is intended to open and shut; if it swings on a vertical axis the linings would be on reverse sides for each half width, and this is the most efficient method.

73. If the masonry be **ashlar,** holes must be jumped through stones to run off water from the **bath rooms,** and their floors should be sloped down to these holes leading through the walls.

74. In **laying out** new buildings the lines are first **pegged** out with **string,** then marked out with **white-wash** and dug to the corners; heed should be given to **avoid** piling deblai or material over the **future site** of subsidiary or auxiliary buildings.

75. The engineer should **observe** that the materials are properly made and fixed in detail, that the money spent tallies with the work actually done, that the designs are not diverged from, and that the necessary working drawings are rightly made and put in hand.

76. The **plinth** surface is level with the paving and floor.

77. The ordinary **ornaments** in **ecclesiastical** architecture consist in string courses, pointed arches, mul-

lioned windows, tracery, pillars, buttresses, flying buttresses, plinths, circular openings which are made on circular centerings precisely similar to those described in Chapter V., No. 102, but continued round the complete circle.

78. The following directions will be found useful in designing buildings: blocks to face the prevalent **wind**, and plan to show by a **meridian** both the north point and direction of prevalent wind.

79. In **associative** buildings the allowance of space for each inmate is not to be less than 80 feet super. and 1680 feet cube for Europeans, or 40 feet super. and 648 feet cube for natives. Also 4′ run of wall length and 3′ sleeping head room for Europeans, and 3′ sleeping room + 2′ interval = 5′ for natives. In solitary cells, 130 feet super. and 2080 feet cube to each European; for natives 100′ super. and 1200 feet cube.

80. Clerestory openings over the verandahs and immediately under the ceiling, are to be made and provided with bonnets to keep out glare and rain.

81. All **tiled** roofing to be **double** tiled if for Europeans; single-tiled verandahs suffice for natives.

82. Plinth to be not less than 2′ above the ground level, in dwellings.

83. All **dwellings** to be provided with **ridge-ventilation** continuous throughout the whole length.

84. When an **associative ward** or similar building is only required for an **odd** number of average inmates, it must be designed for one **more** to make the number even: calling the number n, $n \times 5' \times 16' \times 21'$ high will give dimensions suitable for a well-proportioned building and fulfilling the medical requirements as to space.

85. For a **solitary cell** $13' \times 10' \times 16'$ high up to the tie beam will give the requisite conditions.

86. Males and females are not to be associated in the same ward, even if on separate floors.

87. A jail wall should be 10′ high, 2′ thick coped with brick and covered with plaster and broken glass.

88. **Verandahs** in prisons to be 6′ wide for Europeans and 5′ wide for natives.

89. In order that **ridge ventilation** may shut out rain it should have an **overlap** of 4′. Ventilators should be placed high up, right under the eaves projections, else they must have independent shelter.

90. If possible the **lower** room for Europeans should be reserved as a **day room** and only the upper used as a dormitory.

91. **Cooking houses** may be 10′ 6″ × 10′ 6″, and the roof 9′ 6″ from the ground.

92. **Two** prisoners and no more, are **never** to be confined together in the same room.

93. Native **associative** wards may be designed for $n \times 4' \times 16{\cdot}2' \times 10'$. See (No. 84).

94. **Double doors** to be **not less** than 3′ apart, so that one can be closed before the other is opened.

95. **Low ventilation** is provided for by **fixed louvres.** Screens are to be **open** 1′ clear from the ground.

96. Open barred **doors** on the **weather side** to be **protected** from rain and cold wind.

97. Neither **lavatories** nor privies are to be allowed in the **verandahs.**

98. **Men** and **women** to have **separate** cooking places.

99. **Windows and doors** to be arranged with reference to the **cots.** **Cesspools** are not allowed.

100. **Associative wards,** hospitals, or barracks require a small open verandah on the weather side at least from the south-west monsoon, for **natives.**

101. Lateral crowding is **inadmissible**; rather diminish the **width** of the barrack.

102. Allow 6′ 6″ **wall** and 3′ 6″ **door** space for every two men. Aspect of building always to prevailing wind, for **natives.**

103. The **contagious** ward of a **hospital** to be at the **leeward** corner of the hospital enclosure.

104. In a **hospital** the wards should be 22′ wide × 16′ high up to tie beam; wall length per bed, 9′; surface per bed, 99′ super.; cubic volume per bed allowed, 1584 cu. ft.

105. Every **ward** to have glazed windows, arch heads of doors and windows to have movable **fanlights,** nightstools and urinal closets with separate **ventilation** connected with **corner** of verandah of each ward.

106. Lunatic **cells** require verandahs, good light, and increased **ventilation. Doors** of cells may well be placed **near** the partition, not in the middle, so that the inmate **can** if he wishes sit out of the draught. (See No. 49.)

107. Ablution places to be drained by pipe to a distance.

108. Common **latrines** will answer, but the pans must be altered for **dry earth conservancy,** and the building 9′ clear width.

109. Instead of **windows** in barracks and hospitals, it is preferable to make all the openings **doors** half panelled and half glazed, with movable fanlights in their arch heads, and clerestory windows above them high up under the eaves.

110. Ablution rooms and **latrines** to be in connection by a covered passage with the **corner** of the rear verandah of each hospital.

111. An apartment for 2 patients may be 18′ × 12′;

walls the same height as hospital, and similar ventilation.

112. A shed for 12 **males** may be 48′ × 16′ 6″. Natives may sleep with their heads against the front pillars (102), which are 2′ × 2′, with intervals of 4′ 2″.

113. Prison doors, single, open rails or bars to open inwards, with a long screen of honeycombed tiling in rear. Plank doors are inadmissible, as they obstruct perflation. The necessity for a screen at all is obviated by providing double doors 3′ clear apart (No. 94), with fixed louvres right up to the arch head.

114. Cells may **not** be placed back to back and ventilated by shafts in the centre wall, as perflation is necessary. **Doors,** 3′ barred with iron, not the whole front barred; **windows** 4′ × 3′ iron barred and glazed; **ceiling** opening 8″ square, properly protected in each. Perforated zinc ventilators 2′ × 2′ over all doors and windows, 10′ to 12′ from the ground.

115. In **latrines** 1 seat to every 8 persons seems quite **sufficient** for large numbers; for smaller numbers a larger proportion is necessary, say 1 to every 4 up to 12 persons, 1 to 6 up to 24, 1 to 8 persons above 24.

116. Windows of **honeycombed work** are **objectionable** in **lavatories**; they should be glazed; the end windows should be circular glazed ones placed high up, 3′ diameter.

117. Dispensaries to have one large window **unobstructed,** north or nearly north aspect.

118. At the entrance to an **enclosure** for **jail,** &c., there may be a gateway flanked by a **store** room and **guard room** 17′ apart in the clear, projecting 16′ beyond the enclosure wall, each 14′ × 14′, and the ground floor 13′ to 16′ high, each having one door and one window

opening into the jail, and two narrow windows, iron barred and high up, outside.

119. Blocks of buildings are best **arranged** in **echellon** order across the prevalent wind.

120. Cook rooms and latrines should be excrescences to **leeward**, not built behind dead walls.

121. Ceiling perforations should equal $\frac{1}{120}$ of the superficial area in the aggregate.

122. Floors of cells, and verandah which is preferable to a porch, to be paved with **stones.**

123. Upper half of ground floor **verandah** to be **protected** from glare and rain by fixed curtains.

124. Lavatory should have a cistern, force pump, and elevated tank in the rear, not at the end. **Jennings' fittings** are commonly used. 16 suffice for one company.

125. Unglazed openings for **ventilation** may be made close under the verandah roof where it joins the main walls. Two **rows** of beds, but never more, may be placed between the front and back walls of a hospital or dormitory. One or two beds, but **never more,** may be placed between two adjacent doors or windows.

126. An **approved arrangement** for associative ward, hospital, or dormitory, would be as follows:— Ward to hold 16 beds, 8 on each side, 1 in corner, with 4′ 6″ head room, door 4′ 6″, wall 11′ 6″, occupied by two beds with an interval of 4′ between them, door 4′ 6″, wall 11′ 6″ as before, door 4′ 6″, wall 11′ 6″, door 4′ 6″, corner 4′ 6″, occupied by one bed. This gives a total length of 64′ × 24′ wide. There should be only one end window.

127. Screens are unnecessary and **objectionable,** as they obstruct perflation, which is absolutely indispensable, whereas draughts are not injurious at all as a rule. Beds should, however, be 9″ clear of doors. All

clever contrivances are objectionable in fittings or furniture; simplicity is wanted.

128. **Doors** to be half panelled, half glazed, for barracks about $9' \times 5'$, having over them separate frames, either rectangular or semicircular, also glazed and made to open; the lower inner panels to have holes, perforated metal plates, or fixed louvres, for ventilation. The masonry jambs have usually a splay of $3''$ on either side; this is also objectionable, though convenient.

129. **Chisels, saws**, and even **files** are used to dress **stone**, according to its consistence. Bath stone admits of being readily sawn. Purbanda stone is dressed for fine work with chisels and files.

130. **Balconies** and window **bonnets** may be strutted from isolated corbel stones at intervals.

131. **White eaves** ornamentally cut, and **white** borders, generally suit a building of **basalt** with tiled or corrugated iron roof.

132. Native **latrines** are **not** to be placed face to face; pillars for roof to be $9'$ high, gables open; instead of the front base slab $14'' \times \frac{3'' + 6''}{2} \times 6''$, there is to be a solid stone step $7''$ rise $\times$ $12''$ tread right across the $2'\ 3''$ compartment, and a sloping hole to carry spilt water back.

133. **Doors** of bath rooms to be plank throughout, **not** half glazed.

134. In place of **perforated zinc** sheeting, where prescribed for ventilators, **wire netting** is preferable, the meshes being small enough to exclude birds.

135. Verandah **parapets** to be replaced by **open rails** for perflation.

136. **Tan** for **gymnasium** floors is **not** allowed in buildings used also as **dormitories**; its substitute, **sawdust**, must be guarded from moisture.

137. A **size** of 51′ × 24′ × 18′ 6″ is sufficient for **gymnasia.**

138. **Sill** of bath-room window to be **5′ 6″ above** the floor, window wide and low.

139. Small **privies** to be gabled, with circular openings high up under the eaves, openings also at floor level in front and at each side honeycombed for perflation.

140. There should be two **cook houses** for 11 families —one is insufficient; 40′ is sufficient distance from main building to the offices; 30′ clear is the least distance admissible from privy to cook house.

141. **One** glazed **window** to be made at each end of **cook room,** not **two** small ones. **Bath-room floors** in a dwelling to be depressed 16″. Perflation desirable other than through bed rooms.

142. **Floor** for natives to be **paved** if for **cots,** otherwise to be murram or chunam, say 6″ rubble or concrete, plastered.

143. All **house doors** to have fixed louvres and fanlights to swing a quarter circle.

144. **Six seats** are enough **latrine** accommodation for fifty natives.

145. All **floors** of cook-rooms, dead houses, or wherever slops are liable to be spilt, should be **paved** and close jointed, **never** plastered, as plaster absorbs such things and retains them.

146. To be **comfortable,** a **Dâk bungalow** should be built in two halves, each having a front verandah 30′ long × 10′ wide, one sitting room 16′ × 16′, and a bed room 10′ × 16′ alongside of it, opening into a bath room 10′ × 10′ in the back verandah, which is also 10′ wide and 16′ long, from the wall of bath room at one end to the partition wall which divides the accommodation. The sitting-room should be furnished with

1 bed, 3 half tables, 3 chairs, 1 easy chair, ceiling cloth, and carpet. The bed room, 1 bed, 2 chairs, and a teapoy, ceiling cloth, and carpet; bath room the usual furniture; **recesses** in the walls are very useful as shelves and cupboards.

147. In **dwelling** houses **doors** are usually fastened outside to open inwards, **floors** all plastered, **walls** all whitewashed.

148. At the **corners** of wide **verandahs** the hip rafters may be trussed from the corner of main wall to corner pillar by a tie and two struts.

149. Breastsummers are either **notched** on to pillars surmounted by blocks, or notched on to posts, say 10′ apart, or built into pillar tops, or they may simply rest on pillars, **flat** or perpendicular to the slope of the roof.

150. The **pillars** may be single round, double round, or square; plain, or pedestal and mouldings.

151. Fire-places may be quite plain, without grates or with them, masonry hobs or choolas, chunam pilasters and architrave, mantel with a wide shelf above. Corners where **four walls** meet are the best position for fire-places.

152. All **offsets** or **projections** to be **less** than half the brick or stone projecting, whether built in as a header or stretcher.

153. Iron and similar **supporting** bars, beams, or girders, are simply put through holes in the wall; bulb iron is much used for such purposes.

154. In **many-storied** buildings door and window **openings** are placed **vertically** above each other, to relieve the openings of the weight which would otherwise fall on their arches.

155. For a **thatched** roof the rafters may be 2′ 6″ apart, bamboos 6″ apart, matting sewn or tied on and thatch above. (No. 35.)

156. **Open work** for ventilation may be of honeycombed tiling; of bricks cemented endways in **hexagons** with radii; of bricks cemented end to end, **or** edge to edge in squares of $4\frac{1}{2}''$ side, formed thus: Place 7 bricks on edge, headers, at $4\frac{1}{2}''$ intervals from centre to centre, on them lay 3 stretchers flat, on them a row of headers on edge at intervals as before, and flat stretchers above them, and so on.

157. The very same construction may be turned into **diagonal work** by laying the courses at an angle of 45° instead of level.

158. An **arched** roof would be very good for music, but reflects too much sound for comfort in ordinary buildings.

159. **Furniture** for a bed room in a first-class dâk bungalow may consist of 1 bed, pillows, mattress, resai, mosquito nets, 1 washstand, jug, basin, soap dish, brush dish, and covers, towel horse, wardrobe and drawers, dressing table, looking glass, 1 large teapoy, 2 chairs, carpet, mats, and ceiling cloth.

160. If the roof be **arched**, the end walls may be perforated for ventilation near the top in the middle of their length, right through their thickness; in the key of this opening, which is arched over, there is another opening made vertically through the roof and protected.

161. The usual method of **protecting** chimney **flues** and similar openings at top is by a flat slab of stone laid on brick or stone rests, built at the four corners of the summit of the chimney.

162. Besides **ornamental** roofs, doors, and stained-glass windows (for which faint pale tints are best suited to hot climates, except blue, purple, and green, which may be deep and yet cool), the interior of a room may be ornamented by rich cornice mouldings, panellings in

plaster, mouldings following the outlines of door and window arches, borderings projecting 3″ moulded out to 6″, quirked, and beaded.

163. The **furniture**, ceiling cloth, carpet, and colour washing of the walls, should harmonize or contrast in colouring (see **Chevreuil** on Colours); thus red matches green, purple yellow, orange blue, and so on through their combinations; a very little good taste on this point would cost nothing, and save the eyes from that ceaseless glare of whitewash, so painful in India.

164. A very effective **pattern** for **open brickwork** (I., 147) suited to parapets may be formed by laying bricks as headers flat 4″ apart in the clear; on each **pair** of these 1 stretcher is laid, on it two stretchers in 1 course end to end, on their **junction** a header, and on their **outer** ends stretchers **would** lie if the pattern were continued: this gives openwork in a series of crosses and looks well.

165. **Panelling** either recessed or in relief, rough or moulded, is very effective to ornament massive or broad structures.

166. In order to **fix** a door **frame after** masonry has been completed, two holes may be jumped in the stones on either side at heights of $\frac{1}{4}$ and $\frac{3}{4}$ the total height of the doorway; into these are inserted the butt ends of 4 split pins made of wrought iron and soldered in: holes are now bored in each door post to match the pins and are slid back on to the pins so that the split ends of the pins project through the 2 holes in each post; the split ends are now separated, hammered back, and a wedge of iron driven in between them; then the capsill is fitted on and wooden wedges driven above it between the capsill and the lintel.

167. The **top of a window** may have outside, a slab of stone; and inside, a lintel of fir 6″ × 4″; 2″ 6″

longer than the width of the window, which surplus length is built into the inner face of the wall.

168. Joists may rest in **recesses** left for them in the walls: the joists for a farm-house floor 14′ clear span may be 7″ deep × $2\frac{1}{2}$″ wide at 1′ 6″ intervals, the recesses 9″ deep; the interstices even over the window lintel are built in solid with masonry.

169. Wall under window sill 1′ thick, height of sill stone 3′ 3″ supported at both ends, but 2″ space left under it between supports for settlement. (No. 44.)

170. Inner doors may have straight sides without splay, and lintels of 5″ fir the whole thickness of the party wall.

171. The **chimney** may be advanced 6″ inwards for the jambs which are 1′ 3″ wide and 3′ 6″ to 4′ 6″ high, surmounted by a slab of stone on **edge** backed by an arch; the back wall of chimney may be 1′ thick, front wall 6″ thick. Where two fire-places come just above one another the flue of the lower is run up **one side** of the chimney block, the upper fire-place being placed as near as possible to the other side, say 9″ from it. The total height of chimney 14′; external dimensions of flue, 2′ × 3′ 3″ dressed stones; and has a collar $1\frac{1}{2}$″ deep and 1″ projected, at 6″ from the top.

172. A **wooden** framed **model** is made on the ground and fixed in its place for the gable end.

173. A **space,** the width of the **staircase** and long enough to admit of free head room in ascending the stairs must be **left** in the **floor** above, free from joists, whose ends must therefore be tenoned into a trimmer, as described in (No. 51), by two strong tenons at each end.

174. It must be borne in mind that though wood-work may be at a **safe** distance from **fire-places** as far as any immediate chance of ignition is concerned, yet

long exposure to great **warmth** actually changes its nature so far as to render it much more combustible.

175. Hip and ridge rolls are made of wood, say 2″ diameter, and fixed on **double** pointed **nails** 6″ long, whose lower points, $3\frac{1}{2}''$ long, are driven vertically down into the ridge pole or hip rafter, leaving a shoulder 1″ wide × 1″ high projecting at the top with an upright point $1\frac{1}{2}''$ long, on to which the ridge roll is nailed.

176. Sash bars may be $1\frac{1}{2}'' \times \frac{1}{2}$ inch thick, ovolo moulded on the inside, and rebated outside for the panes to lie against at their edges.

177. A plain **batten door** might be thus made, each door in two leaves, each leaf turns on two hinges, each hinge is screwed with 9 screws (No. 11), the lock and bolts screwed on with 6 screws each, all **screws** to be driven from the **inside** of the house, door $\frac{3}{4}''$ thick nailed on to a frame of 2 uprights and 3 cross pieces tenoned through, wedged and pinned (67): the **right leaf** has an upper and lower bolt which run into eyes screwed against the capsill and ground sill of the door frame on the inside; it has also a rebate on its outside to catch and hold a corresponding fillet on the left leaf in shutting and fastening the door: the door may have a latch with the thumb outside.

178. A **frame** is accurately made as a model for the rafters and collars, or **truss**, on the ground; each **couple** or **truss** is accurately fitted on the model before it is hoisted and put up. The upper ends of rafters may be halved into each other and nailed with 3 nails (V., 57), the collar ends are similarly halved into the rafters and nailed. When the couples are put up they are held in position by nailing light boards across their tops while they are accurately adjusted.

179. Door and window **frames** may be 5″ × $2\frac{1}{2}''$

scantlings if small sized, and nailed back to wood bricks or bond, built well into the masonry, by 2 nails (V., 57) at each place.

180. If the roof is to be **slated,** $\frac{3}{4}''$ **boarding** should cover the rafters close jointed, on to which again the slates are nailed; each board would have 2 nails at each crossing of a rafter, which for a farm house 14′ clear may be $7'' \times 2\frac{1}{2}''$.

181. A door **lintel** for 3′ 6″ span may be 5″ thick, but for a 7′ 6″ span $7\frac{1}{2}''$ is not too much if the weight is great above it.

182. The **wall plates** are laid so that the roof boards would cut the wall (if produced) 3″ from its exterior edge: the boarding (180) is carried close to chimney-stacks and is neatly finished and dressed at the ridges.

183. Instead of **tenons,** a trimmer or similarly loaded piece might very suitably rest on **cleats** simply nailed against the side of the adjacent joists, and this construction has the advantage of not weakening the supporting pieces by cutting them at all.

184. **Flights of stairs** may always be supported as described in (No. 183) instead of wasting the strength of a fine piece of timber by cutting seats for the treads out of it as is frequently done in the strings. See (No. 191).

185. **Floor joists** for a barrack may be $6\frac{1}{4}'' \times 3\frac{1}{2}''$ with clear span of 7′ 6″ resting on girders $5'' \times 6''$ on wooden frames, $4'' \times 2\frac{1}{2}''$ scantlings, 2′ square externally, laid flat on brick or stone pillars 2′ square and of any height suited to the ground so as to bring the pillar tops to the same level; the pillars may thus be 2′ 9″ or so apart; the square frame rests on the pillar, the $6'' \times 5''$ girders on the frames, the $6\frac{1}{4}'' \times 3\frac{1}{2}''$ joists at 1′ intervals apart on the girders, and the $1\frac{3}{4}''$ boarded flooring, ploughed and tongued, is nailed by 3 nails, each $4\frac{1}{2}''$ long, at each crossing of a joist.

186. To ensure the **nails** being properly **driven home** by the carpenter it is well to specify that the flooring shall be **planed** after completion.

187. A very **light roof** may consist of rafters $3'' \times 2\frac{3}{4}''$ at $2' 4''$ intervals, the horizontal laths being $2'' \times 1\frac{3}{4}''$ at $13\frac{1}{2}''$ intervals, covered by shingles $2' 6''$ long, $6\frac{1}{2}'' \times \frac{3}{4}''$ thick, with a half overlap, the wall plate $6'' \times 3\frac{1}{4}''$.

188. The **contractor** should be liable to **fines** in the event of his workmen committing **nuisances,** as they are very apt to do if not looked after, in the bath rooms while in course of construction.

189. Ventilation frames for a barrack might be $2' 4'' \times 1' 6''$ in the clear, the scantlings $5\frac{1}{2}'' \times 4\frac{1}{2}''$, with $1'$ returns at the sill ends to build into the wall (194).

190. Hoop-iron bond may be $1''$ wide, $\frac{1}{32}''$ thick, tarred, and sanded.

191. The **simplest** form of **stairs** is made by fixing two parallel beams called **strings** in a sloping position for the two side joists, nailing down right-angled triangular **brackets** or blocks of wood on to their upper edge so that the hypothenuse lies on the edge of the joist and the right angle is upwards; on these blocks the treads of the steps are fixed. (184. V., 109.)

192. In building a **chimney flue** with **brick linings** a wooden flue is first made, say $9\frac{3}{4}'' \times 10''$ inside, and $1''$ thick, about which the brickwork is built.

193. Scaffolding spars vary from $3'' \times 3''$ to $8'' \times 8''$ or $9''$ diameter; a mere lashing is sufficient hold; four **pegs** driven into the ground suffice for a hold to the butt ends of the vertical poles, or 4 **nails** driven into timber for the same purpose.

194. The outside of **ventilator openings** are fitted with iron gratings, the frames being flush with either surface of the wall; the openings are either slabbed or arched over.

195. For 7′ spans, floor joists may be 6″ × 3″, and 1′ apart, from centre to centre, covered by $1\frac{1}{2}$″ boarding; spans of 9′ 6″ may have joists 7″ × 4″, for 7′ 6″ spans 6″ × $3\frac{1}{2}$″ will suffice, and for 5′ 6″ spans 5″ × 3″, in all cases 1′ centrally apart, for the flooring.

196. Where **trussed girders** are used the **wall plate** would lie over the ends of the girders, under the ends of the joists, and would immediately overlie the **ventilator frames**, of which there might be **four**, placed in the end walls, two in each wall, for the main room of a half-company barrack, each ventilator 2′ 6″ × 9″; for a dwelling room 20′ × 16′ two ventilators would suffice, and for a small room 12′ × 12′ one flue would answer.

197. The requirements for a large building, such as a **half-company barrack**, are shown so minutely in the Government **standard plans**, that it only remains to notice details connected with the specifications for such works.

198. Morter is usually specified to be **composed** of one part stone lime or kunkur lime to two parts of soorki (pounded brick) mixed in a mill. (No. 5, VI., 30.)

199. Stones to be sound or well laminated, none less than 3″ thick; or in a wall more than 2′ thick, no stone to be less area than $1\frac{1}{2}$ square foot, except the few necessary to fill up interstices; in walls 2′ thickness or less, smaller stones may be used, but $\frac{1}{3}$ of the **whole** length of each course must be **headers**, and $\frac{1}{3}$ of these headers must be through stones; the stones to be carefully set, well bonded and laid in morter; the joints to be flushed up **solid** with **morter**, leaving no voids; stones to be laid on their natural beds, the larger ones being hammer dressed where necessary, so that they may rest evenly on their beds without hollows. Great attention is to be given that the system of building up the face and

back of a wall, filling in between with chips and morter, be not permitted.

200. The **outside** of walls in basement and superstructure to have the **joints** dressed 3″ back from the face; faces of the stones may be left rough, with no part projecting more than $\frac{1}{2}$ inch; dressed **joints** not to exceed $\frac{1}{2}$″ thickness. In pillars and archwork the joints throughout not to exceed $\frac{3}{8}$″ thickness.

201. The **inside** of walls to be **plastered**; the plaster to consist of the same ingredients as the morter (198), with the addition of a little **hemp** cut fine.

202. Floor of lower storey to consist of $1\frac{1}{2}$″ boards nailed to joists 4″ × $2\frac{1}{2}$″ at 1′ central intervals, resting on beams or girders 6″ × 5″, five feet apart from centre to centre, supported on masonry pillars 2′ × 1′ 6″ and 4′ 6″ apart from centre to centre.

203. Space under **floors** to be **ventilated** by openings 2′ × 1′ in all the long walls, those communicating with the open air being protected by iron gratings.

204. Ends of girders may be **ventilated** by laying them on wooden or stone slabs and slabbing or arching over their ends, so as to preserve them free to circulation of air, and intact by morter.

205. A bath-room floor may be of flags finely jointed and laid in morter on rubble masonry or concrete well beaten till quite set 6″ thick.

206. Verandah joists may rest on 6″ **corbels** projecting from the wall.

207. Where wood is plentiful and materials suit, a **roof** might be made of split or sawn shingles 6″ wide × $\frac{3}{4}$″ thick, not less than 19″ long when dressed, so that with an overlap of 6″ they may be nowhere less than triple thickness, nailed to battens of (Deodar) wood 2″ × 2″, nailed on to common rafters 3″ × 4″ and 1′ 6″ apart, resting on purlins 5″ × 8″ supported

on king-post trusses 7′ apart, the principals being 5″ × 4″, tie beams 7″ × 4″, double king posts 5″ × 2½″, struts 4″ × 3½″. The scantlings are adapted to the spans taken out direct from **Waddington's** Tables generally.

208. A **roof** may be **secured** from **lifting** by the **wind** thus: Every fourth rafter will be strapped down by iron straps to the breastsummer of the verandah; the breastsummer itself strapped down to the verandah posts, which are secured at their base by angle irons, bolted to the floor; at their upper ends every alternate verandah joist will be spiked to the common rafters of the main roof, the intermediate ones being spiked down to the wall plate.

209. Ceiling boards may be ¾ inch to 1 inch thick, of (fal*u*nda) wood. **Doors** and **windows** to be of, say (Deod*a*r) wood, 2″ thick, hung to frames of (Bair) wood 5″ × 6″ by three iron hinges 6″ long for doors and 3″ long for windows; doors to be panelled; windows glazed.

210. The regulation that **doors** are to be substituted for **windows** in European barracks only applies to the hot plains, not to cool hill stations in India. The doors may be 7′ × 4′ 6″ clear, surmounted by a rectangular head light 4′ 6″ × 2′ 6″, with a semicircular fanlight over it, either or both made to open.

211. The **ends** of **floor boards** rest upon battens, say from 2″ × 3″ to 3″ × 4″, merely laid on the offset running all round the inside of the building at the basement or top of storey for the purpose. (No. 47.)

212. The **exterior** of **ventilation** openings may be well protected by **fixed louvres** to prevent rain driving in; also the base should slope 1 in 12 outwards for the same purpose, and to run off possible leakages; if otherwise protected, being placed close up under the eaves, a

grating will suffice outside (No. 203), or sheets of perforated zinc.

213. No **timber** is allowed within 4′ of a **flue.**

214. The usual **fine** is 20 rupees on detection of rotten timber. All bad work should be pulled down and rebuilt at the contractor's own expense, the question of what **is** bad work being referable to the superintending engineer should the point be contested, which is rarely the case, as it is generally beyond doubt when the **material** is really inferior, whereas inferior **workmanship** is still more manifest on inspection; still, rickety doors and rattling windows abundantly show the ease with which the terms of a specification may be evaded without detection by the use of cheap **unseasoned** wood.

215. Plaster is never to be **floated** till it has been inspected and approved. The wall to be well drenched before the plaster is laid on, the plaster to be not more than 1″ thick, well worked up and rubbed till it dries without cracking.

216. In **pointing**, the old **joints** are to be raked out to 1″ depth, fine morter is to be well worked and rubbed into the joints, the masonry being previously well **wetted.** The **ingredients** are equal parts of fresh well-burnt stone lime and soorki, first ground together dry in a morter mill, then slaked with just enough water to reduce the whole to the proper consistence; next it is worked up in a small hand mill, a little oil to temper it and cut hemp being added as usual.

217. The **sanitary grounds** by which the proper **dimensions** for associative **wards,** &c., are determined having been given, it remains to add the subsidiary buildings. (No. 78–84.)

218. A **cook room** for half a company might consist

of a room 25′ × 16′ clear, walls 11′ high, window 4′ × 4′ 6″ at one end; at the other end two cooking places each 6′ wide, fronted by a 1′ 6″ wall having two 6′ arches with a 3′ pier between, 4′ high to spring of the arch, and 2′ rise; cooking place 1′ 6″ deep, 2′ high, all walls 1′ 6″ thick. In one long or side wall there are ten openings just under the wall plate, each opening being 1′ × 1′ 6″; in the other side wall are two doors, each 7′ × 4′, flat arched, leading into a yard 25′ × 10′ in the clear, having a wall all round it 5′ 6″ high and 1′ thick, coped with stones 2″ thick at edges, and a doorway in the side wall 4′ wide flanked by two pillars 1′ 6″ square plan, coped with stone. The roof consists of shingles on battens 3½″ × 3″ laid 6″ apart on couples 10″ × 2″ with collars 10″ × 2″ (178), of which couples there are three in the intermediate length of 25 feet between end walls, say 6′ apart. The roof projects 1′ 6″ all round except at the chimney end, which is slabbed over, the slab stones resting on blocks 1′ square at intervals of 1′ apart in the clear the whole thickness of the wall, or 1′ 6″ thick. Ridge ventilation continuous throughout. The chimney top may be 3′ higher than the ridge roll (222).

219. A bath and **wash-house** for a **half company** may be 35′ × 30′ 6″ external dimensions, walls all 1′ 6″ thick, having one door in each end wall 7′ × 4′, three clerestory windows 4′ × 2′ 6″ glazed and made to tilt by window ropes in the front wall high up under the eaves. Three fixed louvre windows opposite to them in the back wall, but low down, namely, 3′ 6″ from floor to window sill. These fixed louvres are in frames, 6″ × 5″ scantlings, and each window is 4′ × 6′ high, good strong 2″ venetians. The roof has 2 trusses, with king posts and struts, the trusses 10′ apart, king post 6″ × 6″, principal rafters 6″ × 6″, struts 6″ × 4″ (5″ × 5″ would

have been a better section for a strut, because the piece is no stronger than its **weakest** dimension, and therefore it stands to reason that either 4″ is **insufficient** or 6″ is superfluous), tie beam 10″ × 6″, purlins 8″ × 4″, common rafters 6″ × 3″, at two-foot intervals, boarded and shingled; trusses strapped with iron. Ridge ventilation throughout. Inside the building, commencing from the back wall, there is first a space 6″ clear of the wall, then a trough wall 1′ thick and 2′ 6″ high, then a trough 1′ 6″ wide the whole length of the building, then a trough wall 1′ thick 3′ high, bath compartment 6′ long, wall 1′ 6″ thick, passage 4′ wide, basin stand 5′ 6″ flagged, channelled, and parted, space to the front wall 6′ 6″. There are two water cisterns, one at each corner of the front wall in the space marked 6′ 6″; each is 2′ × 4′ × 3′ deep, bounded by a 1′ wall all round, 6″ clear of the external walls of the building. The bath compartments are 6′ × 4′ 6″ inside. Each has a door 6′ × 2′ to the front, and is separated from the next compartment by a party wall 6′ high and 1′ thick. The furniture consists of four boards of accoutrement pegs, board 2½″ thick, pegs 1½″, and total projection 9″; there are 6 pegs in each board, which is 6″ deep and strongly bolted **right through** the wall. Floor is all flagged, walls plastered.

220. For **jaffery** or **trellis** work **tin tacks** are used, not iron nails.

221. When slight **frames**, as for **verandah balconies**, are put together glued and pinned, they are **wedged** tight in a strong external framework, and the joints well closed. Bamboo pins are used for securing the joints. The **verandahs** themselves always have a **slope** or fall of 3″ towards the outside to run off rain.

222. The proper **pitch** for a shingle roof is from 2 to 1 to 1 to 1. It requires good workmanship to close

the **chimney joint** with the roof; sheet zinc is commonly resorted to, but if this part of the work be not thoroughly inspected while under construction there will always be a **leakage** about the chimneys. The chimney may have a square fillet sloped all round the joint to the pitch of the roof, and plastered.

223. The **weights** which would suffice to **break** a bar 1 inch square and 12 inches between points of support of the undermentioned materials are as below, the bar being **supported** at each end, **not** fixed, and the load being applied in the **middle.**

	lbs. avoirdupois.		lbs. avoirdupois.
Oak	557	Siris	532
Beech	519	Mango	560
Ash	675	Babool	876
Mahogany, Spanish	425	Ebony	861
Mahogany, Honduras	637	Tamarind	816
Cedar	545	Semal	678
Fir	565	Hard*u*	586
American pine	822	P*i*pal	458
Red pine	620	Deod*a*r	586
Teak	683	Hill bamboo	970
Soondree	925	Plain bamboo	686
S*a*l	769	Sandstone	106
N*i*m	752	Cast iron	2431
Siss*u*	706	Wrought iron	5219

224. The **safe load** for the above materials may bear to the **breaking weight**, which is generally written p in formulæ, the following proportions :—

For timber	$\frac{1}{10}$	These proportions represent what is called the **factor of safety**, generally written f. (No. 225.)
Stone and brick	$\frac{1}{8}$	
Cast iron, still load	$\frac{1}{3}$	
„ „ moving load	$\frac{1}{7}$	
Wrought iron, still load	$\frac{1}{3}$	
„ „ moving load	$\frac{1}{6}$	

225. To find the **load** admissible for a **horizontal** beam supported at both ends and loaded in the **centre,** the weight or **load** $W = \left(\frac{B D^2}{L} \cdot p\right) \times f$, where B is the

breadth, D the depth, and L the length of the beam; p is the breaking weight given in (No. 223).

226. If the **load** W is **distributed**, as a floor or flat roof, the beam will bear twice as much weight, or $W = \frac{2BD^2}{L} \cdot p\,f$. The **factor** f is given in (No. 224), and must be used according to the nature of the material; **without it**, the equation simply gives the weight W, which would just break a beam so circumstanced.

227. When the beam is fixed at **one end** and loaded at the other end, $W = \frac{1}{4} \times \frac{BD^2}{L} \cdot pf$; if the load be **either** in the middle **or** uniformly distributed, $W = \frac{1}{2} \times \frac{BD^2}{L} \times pf$; if the load be at a distance m from one end, and n from the other, the beam being **supported** at both ends, $W = \frac{1}{4} \frac{LBD^2}{mn} \cdot p\,f$.

228. Under a **fire-place**, an arch called the **trimmer arch** may be turned, from the wall to the **trimmer** (No. 51), which should then be tied together by iron tie rods.

229. The **weight** P, which would just suffice to **crush** a 1″ cube of various building materials is given below.

MATERIAL: ω =	lbs.	ω =	lbs.
Oak	8,084	Limestone	7,338
Fir	5,748	Red sandstone	2,185
American pine	5,455	Freestone	1,088
Beech	9,363	Hardest brick	2,134
Mahogany	8,198	Underburnt brick	600
Teak	12,101	Sand morter	498
Cast iron	110,760	Ordinary brickwork in cement	521
Wrought iron	35,840	Rubble masonry: $\frac{4}{10}$ of the stone of which it is built.	
Granite	9,249		
Marble	5,500		
Chalk	330		

See (No. 233).

230. The **safe load** W, for the above materials is found to be $\frac{1}{10}$ of ω, the ultimate crushing load given in the Table.

231. The load P in (No. 229) only applies when the column under pressure is too short to **bend**, that is when its **length** is **less** than 7 times its least transverse dimension; a timber whose length was **100 times** its least cross measurement would bend **without any** load if placed in a vertical position; hence **lateral bracing** greatly increases the supporting power of a **strut** or column.

232. As a rule, **struts** of timber, or **posts** under very heavy load should have no cross dimension less than $\frac{1}{10}$ of their length between supports.

233. When the length of a wooden **post** is more than 7 to 8 times its least transverse dimension, the values of P given in (No. 229) must be multiplied as below by a fraction *f*.

Length = L; thickness = *t*.

L = (7 to 8) *t*	*p* remains as in No. 229.
L = (8 to 12) *t*	$p \times \frac{5}{6}$.
L = (12 to 24) *t*	$p \times \frac{1}{2}$.
L = (24 to 36) *t*	$p \times \frac{1}{4}$.
L = (36 to 48) *t*	$p \times \frac{1}{6}$.

234. The **safe load** for any **column** therefore or pillar whose sectional area is S, square inches, will be $W = \frac{1}{10} \times p\ s \times f$, and varies directly as the area under pressure.

235. The load, ω, which would just suffice to **tear asunder** a bar 1″ square, along the grain, is given below for various substances.

	lbs.		lbs.
Oak	11,380	Box	19,916
Fir	12,092	Mahogany	7,966
Ash	17,071	Teak	15,648
Elm	14,795	*Sal*	11,521
Beech	11,380	*Sissu*	12,072

	lbs.		lbs.
Tun	4,992	Copper	19,062
Mango	7,702	Basalt	109,540
Semal	6,951	Limestone	43,816
Wrought iron	56,904	Brick	27,740
Iron wire	42,678	Lime morter	5,975
Iron chains	39,832	Hydraulic morter ..	12,803
Cast iron	18,493	Hempen rope	9,247
Steel	106,695	Leather straps	569

Tarred rope is only $\frac{3}{4}$ the strength of untarred ditto.

236. The **safe load** W, for tension, is

With cords, ropes, and straps of leather	$\frac{1}{3}$
„ metals	$\frac{1}{6}$
„ woods	$\frac{1}{10}$

of the tearing weight given by (No. 235) for each square inch of sectional area.

237. In **ordering girders** see (VIII., 165).

238. Tin is not much used in the metallic form, but as **tin foil** and to coat iron. **Tin plate** is made of sheet iron; charcoal iron, pickled in dilute sulphuric acid till the oxide is cleared off, then washed clean, dried by rubbing with warm bran, put into a bath of melted tin covered with tallow, left there for $1\frac{1}{2}$ hour, removed and dipped into a bath of purer tin for 1 minute, then into a bath of tallow, then set in a rack to cool. The border of tin which collects along the lower edge of the plate is melted in a bath of melted tin, and a sharp blow with a light stick on the edge of the plate disengages it; the tallow is next removed by bran, and the tin plate is ready for market.

239. Wrought **or** cast iron may be readily tinned by first filing, or pickling in sulphuric acid, then washing and dipping in a solution of chloride of zinc; dry without wiping and dip into a bath of melted tin.

240. Iron can be jointed to soft metals by solder, but the joints **must** be **clean**.

Solder	Plumbers' = 1	of tin to	1	of lead.
	Tinman's = 1	„	2	„
	Pewterers' = 2	„	1	„

240a. Contract working is a great advantage in every way to an engineer, as it leaves him at liberty to attend to his proper and important duties, instead of constantly watching the workmen in the minutest detail. **Contractors** should be encouraged in every fair way, but their work very strictly examined to see that it comes up to the quality paid for.

241. Rough dressing ashlar masonry before it leaves the **quarry** is found to save two-fifths of the cost of **carriage.**

242. The **size** of **jumpers** used varies with the rock: for hard rock say $1\frac{1}{2}''$ diameter; loose sandstone and shales $2\frac{3}{4}''$; for shallow holes $4\frac{1}{2}''$; requiring from $\frac{1}{4}$ to $2\frac{1}{4}$ seers of steel to tip the ends. In hard rock a $3'\ 6''$ hole could be jumped using both ends, without sharpening. With the $2\frac{1}{2}''$ jumper a $1'\ 8''$ hole could be jumped in a day; with the $1\frac{1}{2}''$ in hard rock, $3'$ in one day; in hard shale two men could jump two holes, each $3'\ 6''$ deep, in a day; in friable sandstone two men could jump two $2\frac{3}{4}''$ holes $8'$ to $12'$ deep.

243. The **proper charges** are for

Line of Least Resistance. Feet.	Charge of Powder. lbs.	oz.
1	0	$0\frac{3}{4}$
2	0	4
3	0	$13\frac{1}{2}$
4	2	0
5	3	$14\frac{1}{2}$
6	6	12
7	10	$11\frac{1}{2}$
8	16	0

244. The best site for a **quarry** is in the **side** of a **hill,** not at the top. In working a quarry every

3·7 lbs. of **powder** expended ought to give 1000 cubic feet of **stone** excavated.

245. The term **naphtha** now includes **paraffine oil,** distilled from cannel coal or bituminous shale; **bone oil,** distilled from animals' bones; **ordinary naphtha,** distilled from coal tar; **petroleum** or mineral oil, which exudes from bituminous soil or oozes out of bituminous shale.

246. Special practice can alone educate the eye to guess where the geological formations indicate the presence of **petroleum**: it is then a further question requiring a quantitative and qualitative chemical analysis, whether the petroleum be worth working, whether it be plentiful enough and accessible enough to pay the carriage. Generally petroleum may be looked for about the **lias** groups (see IX., 96), bituminous shale and limestone.

247. Paints are generally mixed with boiled **linseed** oil and **turpentine** oil; **mineral** paints are the most durable: the linseed oil is boiled with a little litharge and sugar of lead.

248. Turpentine alone is used with **white** paint, as oil discolours it; when the finishing coat is thus laid on it is said to be **flatted.** The turpentine is called oil, or essence, or spirits of turpentine, known as **turps** commercially.

249. The first process in **painting** is to dry, clean, and smooth the surface to be painted, then to cover the **knots** with **red lead** and **size**; rub with sand paper; holes to be filled with putty; nail heads to be punched in and covered with **putty** made of whiting and linseed oil.

250. The **first coat** of paint, consisting of white lead well diluted with linseed oil, is called the **priming.** Each coat, when dry, should be well rubbed down with sand paper or pumice stone.

251. In repainting old woodwork it should first be scoured with soap and water, and, if smoky or greasy, limewashed. When the old paint is too much blistered to be touched up with colour the whole must be reduced by the heat of a charcoal brazier passed over it.

252. **Wood oil** boiled with a little **dammer** (pitch) may be used instead of paint where the wood is not to be exposed.

253. In laying on the paint the **brush** must be held **perpendicular** to the surface, so that only the **tips** of the hairs touch it, not to be smeared with the side.

254. Plastered and whitewashed walls may be coloured with a vehicle of **water and size** instead of oil. This kind of painting is known as **distemper.** The addition of **whitewash** pales the tint. Milk and water or thick curd and lime water is washed on to form a body for the water colouring.

255. The **water colour** is mixed in a vehicle of half milk and half water, with white of eggs and pure China glue, the glue previously dissolved.

256. The **pigments** used to impart colour, whether to

Whiting powder ..	1 seer	for water colouring,
Glue	0 2 chittaks	

or to linseed oil and turpentine for **oil colouring**, would be (as measured in chittaks)—

Stone colour ..	½ burnt umber, 2 chrome yellow, ½ vermilion.
Light yellow ..	2 chrome yellow.
Buff	2 chrome yellow, 1 yellow ochre.
Green	4 French green powder.
Brown	2 burnt umber, 3 Mina.
Blue	2 Prussian blue.
Purple	2 Mina, 2 Prussian blue.
Pink	2 Mina, 2 China vermilion.
Red	2 red ochre, 2 red lead (strong).
Black	4 lamp black.
Chocolate ..	⅛ lamp black, 4 Spanish brown.

257. Varnish is made by dissolving **resins** in alcohol or linseed oil and turpentine, just as paints are made by dissolving pigments.

258. The following **varnishes** are approved:—

Sandarach	250	
Mastic	64	
Elemi resin	32	
Turpentine	64	
Alcohol	1000	

Anime resin	2 lbs.
Litharge	1 oz.
Sugar of lead	1 oz.
Turpentine	5½ quarts,
Linseed oil	3 quarts.

Copal	300	Copal varnish.
Turpentine	500	
Linseed oil	200	

Pale shellac	750
Mastic	64
Spirits of wine	1000

The above mixtures to be carefully boiled and strained; **boiled** linseed oil to be used.

259. Sandarach, mastic, elemi, anim*e*, copal, and **lac** are exudations from various trees, as p*i*pal, dh*a*k, &c., and foreign trees. **Stick lac** is the rough form as produced on the branches of the tree; the same pounded and cleansed is **seed lac**; the same melted, strained, and dropped on smooth plantain leaves gives a sheet of purified resin known as **shellac.**

260. Brass lacquer is made of—

Pale shellac	1 lb.
Gamboge	1 oz.
Cape aloes	3 oz.
Alcohol	2 gallons.

Gold lacquer—

Pale shellac	$\frac{3}{4}$ lb.
Sandarach	$3\frac{1}{2}$ lbs.
Turmeric	1 lb.
Gamboge	$2\frac{1}{2}$ oz.
Alcohol	2 gallons.

261. **Putty** is made of **whiting** and **linseed oil**, much improved by the addition of a little **white lead**, the ingredients to be well beaten together.

Chalk, Resin, Linseed oil or turpentine, or both, will make a putty.	Putty.

262. In measuring **splayed jambs** they are usually calculated as square, the largest dimension being taken on account of the extra labour in cutting the bricks to gauge.

263. Of **bridges** which have not yet been described there are three kinds, viz. rope, chain, and suspension bridges generally, bridges of boats, pontoons, barrels, rafts on chatties skins or other floats, and flying bridges. The first class require special study, calculations, and models for their best shape and resulting strains, except in the simplest possible cases. The second class have usually to be improvised on an emergency from whatever means are available on the spot, and his own ingenuity will be of more assistance than any work on engineering to the officer engaged on such duty. In throwing a **flying bridge** across a river the following points require attention :—

264. A **flying bridge** is made by mooring a boat halfway across the current of a river, the cable being **floated** throughout its length on buoys, and **long enough** to let the boat, when skilfully steered, swing

as it were through an **arc** of **not more** than 90° from one side of the river to the other.

265. A skilful steerer is wanted for a **flying bridge**, which is worked by the current much as a **kite** is flown in the air, or an **otter** worked in fishing. The **point** in the boat to which the cable had best be made fast is also a nice matter of experiment on the spot; the **longer** the mooring **cable** is the **less strain** will there be on the boat in crossing.

CHAPTER XIV.

NOTES ON GENERAL DUTIES.

1. Amongst the most **useful subjects** about which an engineer can inform himself on arriving in a new district are the following:—

2. What **materials** are available in the district for **building**, such as stone, limestone, brick clay, timber, or metalling for roads; and where does each abound.

3. What **works** are in progress, what is the order of their emergency or **importance**, and are there any **special orders** relating to them requiring attention. What **money** is sanctioned for each, and how much has been expended.

4. **How much** is allowed for the whole district, or what limit is there to the budget grant.

5. What are the current **rates** for labour and **prices** for material, in the locality.

6. What sort of **soil** prevails, and what **foundations** have been found sufficient. How much sand and soorki does the lime require.

7. What **area** do the **irrigation works** water. What has been the cost of construction and yearly maintenance of such works. What are the revenue, tenure, cultivation, indirect irrigation returns, difference in revenue since the irrigation works were brought into operation.

8. What **important works** are there in the province; what did they **cost.** What are the principal routes; how much per mile did they cost. What width and thickness of metal is maintained.

9. What is the **area** of the province, population, industry, crops, rainfall, mean and extreme temperature. What labour is available; is it limited.

10. What are the **flood levels** of the principal rivers, and their velocity. Where is there ground suitable for encamping troops for military operations, &c., in the district. What is the elevation.

11. What European and native **regiments** are stationed in the district.

12. Other **statistics** there are, ignorance of which may produce, to say the least, very awkward results; they are thus given, I think by Capt. Priestley, 74th Highlanders:—1. Situation. 2. Extent. 3. Boundaries. 4. Principal towns. 5. Forts. 6. Markets. 7. Rivers. 8. Works on rivers. 9. Canals. 10. Mountains. 11. Hills. 12. Plains. 13. Woods, forests, or jungles. 14. Roads. 15. Passes. 16. Mines. 17. Camping grounds. 18. Minerals. 19. Manufactures. 20. Soil and productions. 21. Population. 22. Cattle and useful animals. 23. Wild animals. 24. Climate.

13. The points to attend to in actually **taking** over charge are fully given in the D. P. W. Code, Chapter XVIII. The chief matters being to go over the **stock lists most attentively**, for the sake of the storekeepers as well as of the relieved officer.

14. **Measure** each heap of **metal**, which should always be piled to gauge for ease in measuring, on the berm below the side of the road: **count** and weigh **selected** articles of stock, selecting those that look deficient, for proof.

15. **Ask** the relieved officer for a **list** of works in hand or to be commenced, and of orders to be complied with; sources of metal, cost of carriage, prices, &c.; any other useful information, or any matters that may occur to him requiring attention, about contractors and their specialities.

16. The following **list of articles** usually to be found in Government **stores**, with their native names as used by the native overseers and storekeepers, will be found useful. Where no native word is inserted it is because none is in common use, the English name having been adopted together with the article itself.

17. Pronounce the vowels as in Italian, but always **short** except where printed in italics, which are to be pronounced **long**: consonants all **hard** except ch, tsh.

Anchors—langar.
Almirah.
Anvils (pointed)—neai.
Anvils—sadh*a*n.
Axles—tud*a*.
Axes, felling—kulh*a*ri.
Axes, pick—g*e*nti.
Bars.
Bellows—damkash.
Braces (iron)—d*a*ndi barma.
Brass—p*i*tal.
Bricks, burnt—pakke *i*nt.
Raw bricks—katche *i*nt.
Bucket—b*a*lti.
Chain—jar*i*b.
Chair—kursi, or ch*o*ki.
Chest of tools—hathiy*a*r ka sand*u*k.
Iron compass gauge—park*a*r.
Cobler's knife—rambi mochiy*a*n.
Crowbar—kir*o* bar.
Copper—t*a*mba.
Dies—gutka.
File—r*e*ti.
Frames for buckets—charsa.
Funnels—p*i*k.
Gimlet—barma.
Gong—garhiy*a*l.
Gun-metal bushes—p*i*tal ke *a*wan.
Hammer—hath*o*ra.
Hinge—kabza.
Hone—san.

18.

Iron (scraps)—l*o*he ke pur*a*ne tukre.
„ (round)—g*o*l l*o*ha.
„ (English)—Angrezi l*o*ha.
„ (collars)—l*o*he ke band.
„ (hoop)—patra.
„ (rail)—r*e*l ka l*o*ha.
„ (country)—d*e*si loha, or s*u*che patti.
„ bolts—l*o*he ka k*a*bla.
Irons for boats—kishti ka loha.
Iron from old barrows—h*a*th-g*a*ri ka pur*a*na l*o*ha.
Iron (sheet)—ch*a*dar ka loha.
Jumpers mining—sabbal.
Iron jhams—jh*a*mp.
Level, sextant, or theodolite—komp*a*s.
Lime—ch*u*na.
Lime sieve, or riddle—ch*u*ne ka chh*a*na.
Litharge—murda sang.
Level (mason's)—r*a*j ka b*u*nya.
Lamp—il*a*nt*e*rn.
„ (of tin)—kal*a*i ka l*a*nt*e*rn.
Lock—t*a*la.
Log—g*e*li.
Mamooty—farwa, faora, mamati.
Mattock—mattak.
Measure for gunpowder—b*a*r*u*t ka paim*a*na.
Mould—thap*a*.
Mould for bricks—*i*nt ka s*a*ncha.
Mashak.
Measuring tape—m*a*pne ka f*i*ta.
Oil (boiled linseed)—pakka alsi ka tel.
„ (raw linseed)—katcha alsi ka tel.
Planks (boat)—kishti ke lakri.
Perambulator for measuring—payir.
Plated crowns—tagm*a*.

19.

Pole picks (miners')—g*e*nti ka pattu.
Priming wire—s*u*ja.
Port fire—top ka batti.
Pincers—sani.
Poker (iron)—ankara.
Powder barrel—bar*u*t ka p*i*pa.
Packalls—pak*a*l.
Pitch—kushak, or r*a*l (resin).
Packing paper—kaghaz.
Powder—b*a*r*u*t.
Railing—jangl*a*.
Resin—r*a*l.
Roller.
Rammers—durmat.
Saws—*a*re.
Screw—pech.

Slabwood—fare ka lakri.
Sledge hammer—badan.
Stone for grinding lime—kras ka patthar.
Stone for a mill—silli ka patthar.
Soorki—surki.
Spherical—gol d.
Sword—shamsher, or talwar.
Scoop, or spoon—chamach.
Spade—belcher.
Scale (beam for weighing)—tarāzu.
" boards—takhte.
" chains—zanjir.
Screw plates—pech ke takhte.
Spindle for circular saw—gol ari ka tuda.
Saw (vertical)—khara ari, or sidha ari.
" (circular)—gol ari.
" apparatus—golarika shaman.
Scissors—kat.

20.

Steel—aspat.
Tar (country)—dēsi ka luk.
Tar (English)—kol tar.
Tin, block—kalai.
Tap—malsut.
Testers or ring gauges for road metal—sancha patthar kewaste.
Trucks, 4-wheeled—gadda.
Turpentine—tarpainth.
Timber—lakri.
Table—mez.
Treasury or treasure—khazana.
Vice—bank.
Vessels, iron—karai lohe ke.
Wedge—cheni.
Wheels, iron—lohe ke paiyir.
Wheelbarrows—hath gari.
Weights of iron—lohe ke wajan (or wazan).
Wrenches—debri kash.
Wire, iron—lohe ka tar.
White paint—sufeda.

21. The **system of accounts** in the Public Works Department is at present the real weak point in a financial point of view; apart from the mistake of multiplying forms in order to ensure accuracy by their mutual check and corroboration, the present system requires a knowledge of accounts which is not to be acquired by a five minutes' study of a manual on "book-keeping"; and unless an engineer happens to have been in business previously, so as to understand clearly the difference between the debtor and creditor side of an **account current,** and how to post accounts into a **ledger,** he is much at the mercy of others in signing accounts, which are too complicated to be thoroughly understood without a long and careful study, such as he has not always time to give.

22. A curious error, but one most fertile in loss to Government, is commonly made in "contractors' certificates" (Form No. 14), in which I have seen the value of stores issued to contractors actually **deducted** from the **value** of work done by the contractor during the month!! instead of being **added** to **payments** made

to the contractor. The consequences, in a financial point of view are most ruinous to Government, for the contractor finally is paid up whatever balance remains unpaid at the completion of his work, and has meanwhile received a **present** of the Government stores, for which a temporary deduction was made in that month's payment certainly, but this was recouped to him the very next month, when his work was again measured up for payment. The Public Works will always be an expensive department, while such costly errors are possible, that is, until the accounts are simplified, or the engineers taught how to keep them.

23. The simplest **remedy** is to throw all the arranging and posting up of accounts on to the central office of account; requiring from engineers or assistants **only** a statement in the form of a **journal**, in which all Departmental transactions would be clearly entered as they occurred (like an ordinary day-book). A copy of this should be sent in to the Account Office every month, and all accounts would be prepared from it.

24. The engineer might keep a **ledger** for his **own** information, to show what sums remained available on each **estimate**, what **contractors** had been paid and what for; but **only** his **journal** should be **submitted** as the basis of accounts, for actual disbursement.

25. It is a fact, well recognized in business, that a **clear**, concise **statement** requires a more thorough comprehension of the matter, than a mass of forms under which dishonesty and cunning may assume the mask of inadvertence or incompetence, and this is nowhere more true than in the preparation of accounts.

26. As the accounts **exist at present**, the following directions will be useful in filling in, and submitting, the most usual forms.

27. Day-book (Form No. 6). Fill in, in duplicate,

on the date of making a payment. Charge the amount to works, contingencies, or as directed. Send one copy direct to Executive Engineer, together with a receipt, stamped 1 anna if above the value of 20 rupees (and a copy of imprest cash-book). Note in a memorandum that this has been done on such a date, and enter the amount of the charge in the book of **expenditure on estimates**; keep the duplicate copy of the **day-book** in the pigeon-hole for the **month** of payment (not under the contractor's initial letter). Note on the counterfoil or reverse side of the **cash-book** to what work the sum is **chargeable**, the date of the order or **sanction**, and the date of sending the **day-book** in.

28. Imprest cash. Send **with** day-books and receipts, at any time during the month at which payments may be made, but **never** send it separately. As far as possible make all payments at the same time, and get recouped immediately after: keep the money in uncashed cheques, not in specie.

29. Contract certificates (No. 14). Send in a number together, never one by one. Warn the contractors to be present and bring receipt stamps with them on a given day. Call them in one by one, and let them sign the certificate **both** as correct in quantity on the face of it, at the left-hand bottom corner, and then **again** on the reverse side, as having received the amount, **always** stating if for a **final** payment on the work. Then date and sign the paper, observing that the name of work, name of contractor, and authority or sanction are duly filled in, to save future reference, correspondence, and trouble. Now, do the same with the duplicate copy, all except the stamp. The stamped **originals** are sent in to the Executive Engineer's Office. The unstamped duplicates are kept as office copies in pigeon-holes, under the **initial letters** of the

contractors' names. The payment is entered in the **ledger** as paid to the **contractor**, showing what for and date. It is also entered in the **estimate book**, against the **work** to which chargeable, showing to whom paid, the date, nature and quantity of work for which due. It is also entered in the Progress Report.

30. A memorandum of all papers sent in should be kept in the **despatch book.**

31. All the above **instructions** are essentially **necessary**, and a moment's consideration will convince of the necessity for any one of them that might appear superfluous.

32. Bill for **petty contract** work, Form No. 15, is treated precisely as No. 14 Form (29), sent in as below.

33. The only other Form of **constant** use is that for **Requisitions**, Form No. 7. On being asked by any authority, military, civil, ecclesiastical, or medical, to perform work under 200 rupees value, supply him with a Form, No. 7, which he will fill in and sign: if it is for petty work, panes of glass, hasps to doors, &c., send it to the supervisor to fill in details, numbers, measurements, and cost, and to get it signed, if necessary, by authorities of the department ordering the work, noting on the face of the requisition the date when sent **for cost**; on its return, forward to the Executive Engineer, writing the words **For Sanction** and the date across the back. When it comes back sanctioned, copy it into the Requisition Book, number it on its upper right-hand corner according to its order as it stands in the book. Enter the date in the Requisition Book, and **to what chargeable** if any directions are given on the subject. Now put the work in hand, and on its completion get the ordering officer to sign the Form in acknowledgment that the work has been **completed** satisfactorily. Next make out a bill, Form No. 15, in

favour of the contractor who did the work, in **duplicate**; send in one copy **with** the completed Requisition Form to the Executive Engineer, and ask for a cheque to the amount of it. The Completed Requisition Form is the **voucher** to prove that the work has been really done to the satisfaction of the officer who ordered it. The Executive Engineer returns the Form No. 15, with the cheque; the contractor must sign and stamp both original and duplicate of No. 15, and the cheque is then handed to him. (See No. 29.)

34. The matters specially to be **avoided** as tending to confusion are such as **giving work** to **more** than one **contractor** to perform; it may seem superfluous to mention such a self-evident subject, but I have known, say the pucca rubble masonry of a large building, given to five contractors simultaneously!! this complicated by the issue of lime and soorki to one or two of them who also employed it on other works for which they had contracts, portions therefore of all of which works were mixed up in the same contractor's bill, form inextricable confusion, from which it is impossible to determine what the payments were for, what portion of a stock issue is to be charged against each work, or what portions of any work have been paid for, and to whom, especially if the various contractors' receipted bills have been pigeon-holed for years amongst the **monthly accounts** instead of alphabetically under the **contractors' initial letters.**

35. Different **works** should never be mixed up in the same account. Stores may be lent or materials issued to contractors where necessary, but such transactions should be kept separate as purchases, &c., not mixed up in a bill as grounds for deductions from the value of the work done during the month.

36. There is really no end to the confusion which

results from the want of proper training in keeping such accounts. The above are the chief sources of error and loss, to which may be added one more, namely, the insertion of accounts between a contractor and those who supplied **him** with material; when these are complicated gith engagements to supply, partially fulfilled, but finally relinquished before completion, with advances made **by** Government **for** the contractor **to** his suppliers, with authority to retrench subsequently, and with dishonest contractors bolting before finishing the work, it may readily be imagined how impossible it is to check the waste.

37. There are two **remedies** for this state of things, one is to give all the engineers a special practical training in **business matters, not** merely in filling up D. P. W. Forms; the other and better is that described in (Nos. 23, 24, 25); meanwhile it is nugatory to rule that "the Executive **Engineer** will be held **responsible** for all **disbursements** throughout his division," while a trained **native accountant** is held "**responsible** for the accuracy of the **calculations**" on which the payments are founded: it would be simpler to put the calculations and payments **both** into the native clerk's hands.

38. Every survey or plan should have the **meridian**, the **date** when finished, the surveyor or designer's **name**, and a **scale** shown.

39. **Corrections** should **never** be applied in the **field**, the entries should be just as read, and reductions or corrections for true meridian or graduations of the instrument applied subsequently.

40. The most usual **scales** for use in the Department are prescribed in the D. W. P. Code, p. 177, chap. XII., No. 27. For surveys, $\frac{1}{12}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, mile to an inch; for index maps, 1, 2, 4, 8, 16, 32 miles to the inch; for

drawings and designs, 10, 15, 20, 30, 40, 60 feet to an inch. Enlarged drawings, $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{40}$, of actual size, Section horizontal, to be the same as survey. Section vertical, 20 to 100 times the horizontal.

41. The following words, &c., will be found useful, and are not generally given in books, they should be learnt by heart. **Pronunciation** as in (No. 17).

To sprinkle—chirakna.
To crack—chitak *ja*na.
To adhere—chhipakna.
A clod—dh*e*la.
A rebate (in carpentry)—pat*a*m.
A fence—d*i*w*a*l.
Slime—*ga*ra.
Mud—k*i*char.
From side to side—*wa*r p*a*r.
A peg—k*i*l.
An interval—*fa*sila.
At intervals—*fa*sile par.
Fuel—jal*a*wan.
There is no necessity—koi zar*u*riyat n*e*.
To ram—thusna.
Compact—th*o*s.
Stop—bas karo.
A machine—kal.
A revolving machine—charki.
Light—halka.
Slender patl*a*.
It will begin from here—idhar se *u*treg*a*.
Matting—chat*a*i.
Grass—pat*e*ra.
A twig—b*e*l.
To return—laut *ja*na.
Wall plate—d*a*sa.
It leans—jh*u*kta hai.
Before that—us se pahle.
Sandy—r*e*tla.
Root out—ukh*a*ro.
In some places—k*a*i jagah m*e*ng.
Original—asli.
Wherever—jah*a*n kah*i*ng.
Surplus—j*a*sti.
Bucket—dol.
To move, step—sarakna.
Fine masonry—bar*i*k ka k*a*m; or, mah*i*n ka k*a*m.
A tip—nok.
Scrape—ch*i*lo.
In comparison—ba nisbat.
Stick in—g*a*r do.
Uniform—*e*ks*a*n.
Slack—dh*i*la.
Tight—kassa.
A hod—kathra.
Stopped—mauk*u*f.
Mentioned to me—ham*a*re t*a*in zikr k*i*ya.
Has been lost—kh*o* g*a*ya.
Afternoon—tisri pahar.
At five o'clock in the evening—p*a*nch baje sh*a*m ko.
(Go) far, some distance—d*u*r talak j*a*o.
Will it answer?—bar*a*bar hoga, ky*a*.
Cut down and clear away—hadj*a*mat karo.
To bond masonry—kam saras rakhn*a*.
This should have been some time before—yih k*a*m ziy*a*d wakt ke *a*ge karna tha.

42. For ordinary engineering tools, materials, &c., see **Roorkee Treatise,** Appendix C.

For complete sentences on subjects connected with engineering, see **Technical Dialogues,** published at Roorkee, in the Panj*a*b.

For names of engineering stores, see (No. 17).

43. A **general sketch** of the usual manner of conducting ordinary **business** matters as regards the **transmission, purchase,** and **sale** of goods, appears

such a very necessary addition that no apology need be made for inserting it.

44. A merchant or commission agent will undertake the supply or transmission of almost any sort of goods. If these are specifically **ordered,** the parcel is called an **indent.** If it is adventured by the merchant on the chance of being sold, the shipment is generally called a **consignment.**

45. The process is **clearer** when **illustrated** than when explained by description; therefore an example will be given: suppose L. D. and Co., at Sydney, want to sell 113 casks of produce, in London:

L. D. and Co. make out a **statement,** describing the goods, giving Nos. and marks upon them. They get them examined and passed, cleared and shipped on board whatever ship the ship-brokers have **on the berth** for London, at the best rates of (54.59) **freight** the ship-brokers will allow. They get the **bills of lading** signed by the captain, purser, or **stevedor,** as he is called. One copy of this paper and the **marine insurance policy** are forwarded **by** the bank on which L. D. and Co. have drawn against the value of their shipment, **to** that bank's London agent.

46. On the **bills of lading** is mentioned the name of the firm, who are L. D. and Co.'s London **correspondents,** to whom the shipment is to be handed over on arrival in London. One copy of the **bills of lading** is sent to these correspondents. On the strength of it they claim the parcel, and on a sample being sent, may ask their **brokers** to value it, choose the broker who names the highest price, and empower him to sell the shipment **to arrive,** or else they may await arrival and sell **on the spot,** as appears most profitable.

47. The **broker** pays into the hands of the bank's London agent (45) the amount which L. D. and Co.

have drawn. Then the bank's agent surrenders the shipping documents, and gives a **release**, on which the broker can dispose of the shipment. He gets the goods sampled and arranged in **lots** for sale. After selling, he makes out the **broker's account sales** for the whole.

48. Generally the correspondent's clerk attends the sale, which is duly advertised, and **checks** the **prices** as each lot is knocked down. The broker keeps the bank agent's **release** and **bill of lading**, sends an invoice and draft to the correspondent **for** whom he has sold the shipment **belonging to** L. D. and Co., of Sydney.

49. In the **sale advertisement** a **prompt day**, as it is called, is mentioned for payment by the purchasers of the various lots, on either side of which **interest** on the money is to be allowed or charged.

50. The broker **charges interest** in his **account sales**, for what he advanced to the bank's agent, in order to possess himself of the **shipping** documents and **release**. This interest is due to the **prompt day** (49).

51. On receiving the **broker's account sales**, the London correspondent makes out **his account sales**, by adding the charge for marine **insurance** policy and stamp commission postages and petties.

52. A **reference** to the ledger, journal, and bank book, will ascertain the amount paid for marine insurance.

53. Let us now suppose a converse case, say Messrs. R. P. and Co., of London, are to ship goods from London to India. The complete process would be as follows:—

The first step is to ascertain from the weekly shipping list what **ships** are **on the berth** for the port of delivery, and arrange with the **ship-brokers** about the rate of **freight** they will charge, and the latest **date** of shipment. (See No. 59.)

54. The goods being packed, are sent down by land or by water to the **docks**, and a receipt is taken from the superintendent of the docks: then the clearance papers are made out and signed; and after examination by the dock searcher, the goods may be passed and shipped, a receipt being given by the mate, master, commander, stevedor, or purser, for them when put on board. On presenting this **stevedor's** receipt to the ship-brokers, they will accept the **bills of lading** and hand them to the **commander** of the ship for **signature**. When this is done the ship may leave, as the **marine insurance** can be effected subsequently, or in case of delay a provisional policy can be obtained.

55. An **invoice**, descriptive of the goods, is now made out, attached to one copy of the **bill of lading** and marine insurance **policy**. These papers constitute the **shipping documents**, and are deposited all together at a suitable bank, upon which a **percentage** of the value, say 75%, can be drawn against the shipment by R. P. and Co.

56. The **bank** sends the **shipping documents** to its **agent** at the port of destination, and the agent surrenders them to the **consignees** mentioned in the **bills of lading** on being paid the amount of R. P. and Co.'s **draft** besides **freight** and **insurance** dues.

57. The **consignee** hands the **shipping** documents with the bank's **release**, to his broker, who then proceeds to claim and dispose of the shipment, and make out his account sales, on which the consignee makes out his account sales and remits it to R. P. and Co., together with a bill or cheque for the **balance**, and this concludes the transaction.

58. The ordinary process in **remitting money** is as follows:—Suppose B. and Co. of Newfoundland, owe R. P. and Co. of London money, and wish to pay it, B. and

Co., having a credit with the (Union) Bank of Newfoundland, draw **through** the (Union) Bank of Newfoundland, **on** the (Union) Bank of London, **in favour of** R. P. and Co. **for** the amount; and send the **draft** (which is called a **bill** if at *n*, day's sight, or *n*, months after date, and is called a **cheque** if payable on demand, that is across the counter, or immediately on presenting it), in an envelope to R. P. and Co., who drop it into the **acceptance box** in the lobby of the (Union) Bank of London, at any time, and call for the document next day after twelve noon; by which time the (Union) Bank of London will have **accepted** the bill, which is now called an **acceptance**, and the money will be paid to R. P. and Co. when the bill arrives at maturity, provided always that the (Union) Bank of Newfoundland have **a credit** with the (Union) Bank of London to the **amount** of the **draft**, otherwise the draft would be **dishonoured** by a "**non-acceptance.**"

59. The actual process in **clearing** the goods for shipment or export from London, is as below:

First make out in duplicate the **export shipping notice and declaration**, a form which gives marks, numbers, and full description of the goods to be shipped. **Take** this form to the **export officer** of Excise at Tower Hill: if the duties have been duly paid this officer numbers the paper on the upper left-hand corner and fills it in, whereupon you must sign it in duplicate: The officer keeps one copy and puts the other with the **shipping bill** and **pricking note** into an **open** cover.

60. The **export shipping** notice and **declaration** is addressed to the export officer of Excise, Tower Hill; it is to give **notice** of an **intention** to ship the goods; on the back is a **declaration** that the duties have been duly paid.

61. The **pricking note** is in black ink if the goods are sent by water, red if by land; it is addressed to the **out-door officers** on board the ship.

The **pricking note** is signed by the

.... **Searcher**, as having examined the goods.	.... **Master**, mate, or out-door officer, as having received the goods on board.

62. The **shipping bill**, with value declared by the exporter, is kept at the Custom House, Thames Street; the numbers and description of goods on it must precisely correspond with those on the other papers, as any **mistake** will vitiate the papers.

63. Should any **mistake** occur, it can only be thus rectified. First, make the necessary correction on the **export declaration** at the **Excise** office; next, under cover to the **Customs**, and there correct in the **shipping bill** on the "ship's file"; then fasten up in a cover and give to the clerk, who, having initialed the correction in the shipping bill and shown it to the slip clerk behind him, **stamps the cover**, which must now be taken to the searcher's office at the docks, who will correct the numbers or description on the **pricking note**: he will not receive the papers unless under **closed cover**; if accidentally or unavoidably opened, the cover must be re-sealed at the Customs long-room in Lower Thames Street with the Government seal.

64. Continuing from (No. 59), the open cover is to be taken to the long-room, Customs; the clerk compares the papers therein and returns all but the **shipping bill**, which he keeps. Now put the two papers into the **Excise cover** again, and fasten it up, handing it to the same clerk, who then stamps it on the front; it must now be taken (or sent) where it is directed, namely, to the searcher's office at the docks; or the licensed lighter-

man who conveys the goods may take the documents with him to the searcher's office.

65. The **rate** of insurance is ruled by the class of ship, the reputation of her commander, and the port of destination.

66. **Incidental charges** include postages and petties, drink money, &c.

67. **Bills of lading** may either be made out to a specified consignee or "to order"; in either case the intended person must pay the charges and obtain the bills of lading properly endorsed and the bank **release** before he can claim the consignment. Each copy of a bill of lading is stamped 6*d.*

68. **Freight** varies so much owing to the fluctuating demand, scarcity of ships, quantity of goods, war.

69. A **ton** of cotton or jute is five **bales** of 300 lbs. each, usual **freight** might run from 1*l.* 15*s.* to 4*l.* 5*s.* per ton between India and England.

70. A ton of **beer** would be 40 cu. ft., say 33 to 35 dozen quarts, or 8 four-dozen cases, or 4 hogsheads bulk, and for such goods freight might run 1*l.* 5*s.* to 2*l.* 10*s.* between England and India.

71. **Tea is packed in 80-lb. chests.**
Rice, in bags, each weighing 2 bazar maunds, or 164$\frac{4}{15}$ lbs.
Linseed, " " " "
Cotton and jute, in bales (No. 69).
Coffee, in cases or bags, various weights, 1 to 2 cwt.
Silk, in bales of 2 maunds 2$\frac{1}{3}$ seers—say 153 lbs.

72. **Shipping documents** include the **shipping bill, clearance papers** at the Excise Office, Customs, and searcher's offices, and the **bills of lading** with the **insurance policy.**

73. **Exchange** at 2*s.* 2*d.* on India, means that money is so scarce in India or so plentiful in England that 2*s.* 2*d.* would only **purchase** one rupee.

74. **Ex-ship** and **landed terms** mean respectively the cost, freight, and insurance, on the one hand, and all the charges included in an **account sales** on the other.

75. **Consignments**, if duly specified, may be sold "**to arrive**" at a slight loss on the prices they would have fetched if "**on the spot**": but there is danger in selling **to arrive**, if the whole shipment does not turn out exactly the same as the sample shown to the purchaser.

76. **Merchants know**, for instance, that the **whole amount** of cotton available for the English market, say in America, does not exceed 750,000 bales, because producers cannot afford to **store** it, and if sent it is **recorded.**

77. The **freight** is generally endorsed on the back of the **bill of lading** by the **ship-brokers.**

78. The term **average due** refers to the **prompt day** (No. 49). The consignee who **paid up**, to obtain the **shipping documents** from the bank, charges interest up to the **prompt day**, in his account sales.

79. The **freight** and **charges** may be paid in advance or payable on delivery, as stated in the shipping documents. If payable, for instance, in India on goods shipped from London; **exchange**, say @ 2*s*. 2*d*.; **freight** at 8*d*. per dozen quarts; first say 1 doz. : total shipment : : 8*d*. : amount of freight; reduce this amount to shillings, then say $2\frac{2}{12}$ shillings : amount of freight : : 1 rupee : freight payable in rupees. **Primage at** 5% to 10% must be added.

80. In an **Account Current**, John Brown **Dr.** means that John Brown has **cost**, has **received**, or has somehow **got to pay.** John Brown **Cr.** means that John Brown has **paid**, has **been sold** for, or has somehow got to **receive.**

81. **Never** should **ditto** be written in a column of **figures**, it throws the eye out and will not add.

82. Storage rent in India might cost 2 annas per month per package.

83. A charge is made for "**Del credere**" with commission and brokerage.

84. Duty must be paid on the **whole** shipment, whatever breakages there may be or other damage, provided the shipment arrives in port.

85. Bond charges mean **storage rent** when goods are left in a bonded warehouse at the docks, duty unpaid.

86. Sold to **sundries** @ 4 m/s. means sold to sundry purchasers giving them four months' credit.

87. To fill up means when packages are damaged or broken and one has to be broached to fill up breakages or deficiencies in others.

88. Premium of exchange; there is such a possibility as **discount** of exchange, sometimes the bank wishes to purchase bills, but they take profit both ways, if you want to buy, you must buy at 101 say or sell at 99.

89. The **average date** named in an **account sales** is found by calculating the average of the various amounts due and their respective dates.

90. The expression "**no dependency**" in an account sales, means no remainder, no balance to be accounted for or paid, account closed in fact.

91. The **value of money** after exchange into foreign currency is thus found. Suppose 4*l.* 11*s.* 8*d.* at $9\frac{1}{2}\%$ exchange on Montreal. At **par** of exchange, 100*l.* English = 108*l.* Canadian currency; also 1*l.* = \$4·80. Hence the value of *n*, pounds sterling is found by a simple proportion, thus $108 : 109\frac{1}{2} :: 4{\cdot}80 : 4{\cdot}86$ dollars \$ in 1*l.* sterling, then $\{£4 + \frac{11}{20} + \frac{8}{240}\} \times 4{\cdot}86 = \$\,22{\cdot}31$ the value required.

92. Gold at 140, means that 100 dollars or pounds sterling in **gold** are worth 140 dollars or pounds cur-

rency. When that is the case in America 1*l*. English = 4·88 dollars in **gold**, or = 6·85 dollars in paper (greenbacks).

93. Jute cuttings being quoted at ten guineas "**cost freight and insurance**" means that there are purchasers who are willing to give that price per ton, and to pay the expenses of landing, &c., themselves.

94. **Cargo** and **merchandise** are synonymous terms; ships **stores** are issued on requisition for use on board.

95. **Exchange** is a most important subject to understand fully and clearly. Suppose you wish to pay money which is due in **Madras** and want to know whether the best way would be to send a **remittance**, or let **them draw** upon you, also whether to remit direct or circuitously through foreign exchanges.

96. **Direct bills** have only one brokerage to pay, namely, on buying; indirect bills pay brokerage on both buying and selling.

97. For **remittances** that **rate** of exchange is called **best** which gives the variable price **highest** in **foreign** money, or **lowest** in the money of the place operating.

98. For **drafts**, or **returns**, that is for making a payment by the converse method, viz. by allowing your creditors to draw upon you, that **rate** of exchange is called **best** which gives the variable price **lowest** in foreign money or highest in the money of the place operating.

99. If **remittances**, or **returns**, are made, to or from, say Paris, at London, in Amsterdam **paper**, the transaction is said to be negotiated **through** Amsterdam.

100. The regular **charges** are $\frac{1}{10}$% **brokerage**, the **stamp** on the draft, and if transacted through an agent, $\frac{1}{4}$, $\frac{1}{3}$, or $\frac{1}{2}$% **commission.**

101. Suppose 1000*l.* sterling is to be paid in Paris and the rate of exchange is at 25·55 @ 3 mos. sight =

		Francs.
		25,550·00
If turned into cash there, deduct 3 months' interest at 4 %		255·50
Net	Frs.	25,294·50

Again, 1000*l.* upon London sold in Paris @ 25·10 will cost

		Francs.
		25,100·00
Add for loss of interest, 3 months at 4 % till bills mature		251·00
Expense		25,351·00
Net proceeds		25,294·50
Difference	Frs.	56·50

102. Suppose you have an order to execute from Frankfort for bills either

Call these rates g,	Upon Hamburg at	..	13–10
	„ Amsterdam	..	12–1
	„ Paris	..	25·60 as limits,

whereas at present the prices quoted for these places are

Call these present rates p,	Hamburg ..	..	13–9½
	Amsterdam	..	12–0
	Paris ..	..	25·50

To find which paper would be best, let F = the foreign rate, and S = the home or sterling rate.

$$\text{F. Hamburg} \ldots = \frac{p}{g} = \frac{13\frac{19}{32}}{13\frac{10}{16}} = \frac{435}{436} = 0{\cdot}9975,$$

$$\text{F. Amsterdam} = \frac{p}{g} = \frac{12\frac{0}{20}}{12\frac{1}{20}} = \frac{240}{241} = 0{\cdot}9950,$$

$$\text{F. Paris} \ldots = \frac{p}{g} = \frac{25{\cdot}50}{25{\cdot}60} = 0{\cdot}9960.$$

Hence, Hamburg gives the best rates of exchange, Amsterdam the worst.

103. Suppose you have an order from Frankfort to **draw upon** Hamburg at 13–12 as a limit, whereas prices of bills on Hamburg are at present quoted in London at 13–13$\frac{1}{4}$.

$$\text{S. Hamburg} \ldots = \frac{g}{p} = \frac{13\frac{12}{16}}{13\frac{53}{64}} = \frac{880}{885} = 0 \cdot 9940.$$

104. If you give me an order from Hamburg to **remit bills** on Amsterdam at 12–2, and to **draw upon** Paris @ 25·45, or **equivalent** rates; whereas the present rates quoted are 12–2$\frac{1}{2}$ on Amsterdam and 25·50 on Paris, should I execute your order?

$$\text{remit} \quad \text{F. Hamburg} \ldots = \frac{p}{g} = \frac{12\frac{5}{40}}{12\frac{1}{10}} = \frac{485}{484} = 1 \cdot 002;$$

$$\text{draw} \quad \text{S. Paris} \quad \ldots = \frac{g}{p} = \frac{25 \cdot 45}{25 \cdot 50} = \frac{509}{510} = 0 \cdot 998.$$

Here the advantage of the fraction for the remittance is equal to the loss on the fraction for the draft; therefore there will be no loss incurred by my executing your order.

105. **Money** may be **paid** by writing out an order, called **a draft** (No. 58), of which the following is an illustration:—

£214 14*s*. 6*d*. Due 3rd December, 1868.

London, 30*th May*, 1868.

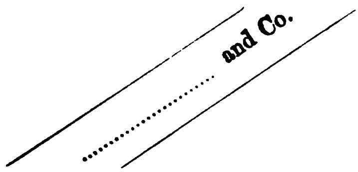
Six months after date pay to our order Two Hundred and Fourteen Pounds, Fourteen Shillings, and Sixpence, ——— value delivered.

To MESSRS. ———

(Signed by *No. 44.*—say *Accepted* *Payable at the*

If the above **bill** had been drawn at six months' sight the words "Accepted (31st July)" would have been written across its face to show that it was presented for acceptance on the 31st July (No. 58): this is called **sighting** a bill. The above bill is thenceforth called A. B. and Co.'s **acceptance.**

When ______________ have **endorsed** the bill it becomes negotiable wherever they have credit; but if



it is crossed, it is then only payable to a bank, as an additional safeguard.

It is usual to make the applicant name the amount, number, and **in whose hands** a bill is before surrendering it.

106. The **rates of exchange** and **values of foreign money** are so well known to merchants and so little value to others that there remains no object in inserting them here.

107. The **following prices** may, however, be very interesting, and at least form an addition to useful practical knowledge. They are selected from averages of the **London market** reports:—

		£	s.	d.		£	s.	d.
Aloes	per cwt.	1	10	0	to	16	10	0
Arrowroot	per lb.	0	0	2	,,	0	0	3½
Barley	per 400 lbs.		..			1	16	0
Beeswax	per cwt.	8	0	0	,,	12	0	0
Bacon	,,	2	8	0	,,	3	2	0
Beef	per 304 lbs.	5	10	0	,,	6	10	0
Bamboos	each	0	0	0⅛	,,	0	0	1½
Camphor	per cwt.	7	0	0	,,	7	10	0
Cardamoms, Madras or Ceylon	per lb.		..			0	2	6

		£	s.	d.		£	s.	d.
Cardamoms, Malabar	per lb.	0	6	6	to	0	8	0
Castor seeds	per cwt.	10	0	0	„	13	0	0
Cloves	per oz.	0	0	2	„	0	0	4
Coir rope	per ton	17	0	0	„	37	0	0
„ yarn	„	24	0	0	„	62	0	0
Castor oil	per lb.	0	0	5½	„	0	0	7
Cocoa-nut oil	per ton	50	0	0	„	58	0	0
Coffee, Mocha	per cwt.	4	9	0	„	6	12	0
Cassia lignea	„	5	12	0	„	6	5	0
Cinnamon	per lb.	0	0	9	„	0	2	8
Coffee, ordinary	per cwt.	2	11	0	„	5	5	0
Cotton, 5¾*d.* to arrive, to 11*d.* on the spot	per lb.		..			0	0	11
Cheese	per cwt.	2	0	0	„	2	18	0
Clover seed, duty free ..	„		..			1	15	0
Corn, Indian	per 480 lbs.		..			1	18	0
Fibre	per ton	21	0	0	„	45	0	0
Flour	per 196 lbs.	1	9	0	„	1	14	0
Gingely seed	per qr.	3	0	0	„	3	15	0
„ oil	per ton		..			50	0	0
Ginger	per cwt.	1	6	6	„	6	10	0
Gum Arabic	„	2	5	0	„	3	5	0
Gutta percha	per lb.	0	0	4	„	0	2	6
Hams, green	per cwt.	2	12	0	„	2	16	0
„ dried	„	3	0	0	„	3	2	0
India rubber	per lb.	0	1	1	„	0	1	9
108.								
Jute (hemp)	per ton	16	0	0	„	23	0	0
„ cuttings	„	11	0	0	„	12	10	0
Kuskus	per cwt.	1	5	0	„	1	10	0
Linseed	per qr. of 410 lbs.	2	18	0	„	3	6	0
„ cake	per 2240 lbs.	10	0	0	„	12	0	0
Lard	per cwt.	3	6	0	„	3	8	0
Malacca canes	each	0	0	1	„	0	0	10
Mother of pearl	per cwt.	6	0	0	„	13	0	0
Mace	per lb.	0	1	2	„	0	3	7
Nutmegs	„	0	1	2	„	0	4	1
Ostrich feathers	per lb.	0	10	0	„	30	0	0
Oats	per 304 lbs.	1	6	6	„	1	7	6
Pearl ashes and pot ashes ..	per cwt.	1	12	6	„	1	15	0
Peas	per 504 lbs.	2	3	0	„	2	4	0
Petrole m	per gallon	0	1	3	„	0	1	5
„ crude	per 252 gallons		..			11	10	0

		£	s.	d.		£	s.	d.
Pork	per 200 lbs.	4	0	0	to	4	2	6
Pepper	per lb.	0	0	3¼	„	0	0	5
„ white	„	0	0	5	„	0	1	6
Poppy seed	per qr.	2	18	0	„	3	2	0
Rattans	each	0	0	0⅜	„	0	1	3
„	per 100	0	2	0	„	0	7	7
Rape seed	per qr. of 410 lbs.	2	11	0	„	2	19	0
„ oil	per ton	34	0	0	„	41	0	0
Rice	per cwt.	0	9	6	„	0	18	6
„ from Java	„		..			1	4	0
Rhubarb	per lb.	0	1	6	„	0	11	0
Rosin	per 112 lbs.	0	6	6	„	0	14	0
					and	0	18	0
Sago	per cwt.	0	17	0	to	0	19	0
Saltpetre	„	0	19	0	„	1	0	6
Senna	per lb.	0	0	1½	„	0	0	9
Shellac	per cwt.	1	2	0	„	6	0	0
Sugar, duty paid	per ton	39	0	0	„	40	0	0

109.

		£	s.	d.		£	s.	d.
Sugar, currant clayed	per ton		..			27	0	0
Tapioca, 3*d.* to 5½*d.* per lb.	per cwt.	1	6	0	„	1	12	0
Teas, duty paid, Congou 2*s.* 6*d.* per. lb., to black leaf	per chest		..			8	15	0
Teeth, elephants	per cwt.	27	0	0	„	46	0	0
„ sea horse	per lb.	0	0	9	„	0	8	6
Tobacco, prices in bond ..	„	0	0	10	„	0	1	4
					and	0	2	9
Tortoiseshell	„	0	4	6	„	1	0	0
Turmeric	per cwt.	0	17	0	„	1	4	0
Turpentine	per 112 lbs.	0	8	6	„	1	11	0

110. For **other prices** of every imaginable kind of article, stores, stuffs, furniture, instruments, tools, crockery, glass, wines, &c., at the **cheapest** rates, see "A. and E. Cohen's prices current," London.

CHAPTER XV.

PRINCIPLES OF LAW.

1. A **clear conception** of the **principles** on which all legal conclusions are based is so necessary to a man of business, and specially so to a **Government officer**, whose duties bring him into contact with existing rights and tenures, and with corporations, companies, and bodies whose nature he should clearly understand, that no apology seems called for in appending one short chapter, which it is hoped will furnish a clear and complete insight into such matters.

2. No **treatise** on law can do more than **show** one the **legal aspect** of his case, whether of **contract** or otherwise; thus indicating the view a judge would take of the matter, and guiding him to a decision **whether** it would be **wise** to refer his case to adjudication.

3. As it is **impossible** to render any **partial** view of such a subject complete in itself, so wrapped up are the various principles, a very short **sketch** of the **whole** will be given: and though this subject is just as foreign to engineering proper, as chemistry, geology, or a knowledge of business matters and how to keep accounts are, yet it is one in which certainly every experienced engineer has **felt** the **want** of knowledge, and one which cannot be neglected long with impunity by anyone connected with public works and public duties.

4. To be **obliged** is to be tied: an **obligation**, there-

fore, in its essential signification, is a restriction of natural liberty, produced by reason or conscience. There are such things as special obligations, but it is only where a **general** and **permanent obligation** exists that we have a **law.**

5. **Advice** or **counsel** implies that he who gives it has no share in imposing the obligation to act accordingly.

6. **Covenants** or **compacts** imply equality.

7. **Liberty** or simple **permission** implies indifference, and does **not** include **protection** for its exercise. When **protection** for the exercise of a liberty or performance of a duty is **added,** the latter becomes a **right** with reference to those who are prohibited from interrupting the exercise or performance, and remains a **liberty** as regards the lawgiver. Such prohibitions are made by means of legal **obligations.**

8. **Laws** are divided into **arbitrary** or positive **laws,** and **necessary laws** which bind all mankind independently of all human institutions.

9. The **punishment** or **reward** attached to a law is called its **sanction**; arbitrary laws are repealed by withdrawing the sanction.

10. **Ethics** is the science which acquaints man with his duty and the reasons of it.

11. **Morality** relates to **principles** of action: these, to a very uncertain point, are regulated by the **Church**, and concern the spirit.

12. **Law** relates to precise and definite **rules** of external **conduct,** which are compulsory, on the ground of public or common interests, the **enforcement** belonging to the **State.**

13. **Positive law** consists of rules of conduct, instituted by a lawgiver, and enforced by artificial sanctions.

14. The authority of public or common **interests**, where the members are rightly associated together, or grouped into a community, is a **natural right**; and **human law** is supposed to be founded upon a reasonable and humane interpretation of **what** the best interests of the community are, and **how** they may best be furthered.

15. The **limits** accordingly of natural law **cannot** be **defined**, as those limits will depend on the amount of perception or intelligence on these two points in the mind of any particular jurist.

16. The **knowledge** of **natural law** is founded upon reason, observation, or **experience.**

17. **Reason** alone is **no motive** to action, it only serves as a guide **how** to act; the **motive** power being supplied by **desire** or aversion.

18. The **success** of persuasives or dissuasives in any particular case will vary as the strength of the **motive,** not as the clearness of the **reason**; for motive belongs to the **character** of the spirit, reason only to the **mind,** which obeys the inclinations of the character, pointing out ways, means, and reasons, for attaining what is desired; and also **showing** what **ought** to be desired.

19. The first impulsions of Providence are usually through the **natural sanctions,** which have their rise in the human **instincts** and passions. They deal with **motives** alone at the first. If these be disregarded they gradually cease, and the operations of Providence appear more and more remote and confused until the man lapses into a state where natural or **external law** is the only means of preserving order by the **fear** of **punishment,** to which end it is effectual exactly in proportion to the **certainty** of detection and **immediate** punishment. If there be a chance of escaping detection or avoiding punishment the law does harm by

enlisting the higher powers of the mind in the commission of evil by **cunning.**

20. Natural sanctions are recognized by reason, instinct, experience, and the human senses, **Love** being the highest. Lest love should perish for want of its due exercise in serving and pleasing others, **Society** is provided, the society taking its nature from the common **interest** which binds its members together. Again, lest **love** should be dissipated by too wide a range, circles of proximity are also instituted, the closest and narrowest intimacy claiming the highest love, as the conjugal; 2, the domestic circle; 3, religious; 4, country; 5, universal philanthropy.

21. Every **member** of human **society** has certain **rights** until he forfeits all or any of them by misconduct; these rights are

> **(1) A right to life and safety of his person;**
> **(2) A right to acquire property by harmless means;**
> **(3) A right to his true good reputation;**
> **(4) A right to personal liberty.**

All other rights arise from two artificial institutions, namely, **property** and **marriage.**

22. The only real **essential** in the **marriage** of two suitable persons is their **mutual consent: Monogamy** made binding for **life** has no sanction either in God's law or in reason; it may be the most perfect happiness where the parties are suitable to each other, or the most perfect misery where they are unsuitably bound together. **Polygamy** is not forbidden either by God's law or the law of nature, nor is divorce wrong in itself.

23. The ground of parental authority is parental **affection**; Puffendorf and Grotius both maintain that parents may sell or pawn their child in case of extreme necessity.

24. Exclusiveness and **permanence** are the chief

external characteristics or **signs of** a private dominion over things, which are then called **property. Exclusiveness** means the **sole** right of using and directing the use; **Permanence** implies an actual right to the very substance of the property possessed.

25. Labour is a chief cause of private property where property is sought as the reward of service.

26. It must be clearly borne in mind that human law concerns **only** external or material actions; and it may be assumed as an axiom that the moment a human law attempts to touch the **motive** or moral attitude of the spirit or character, a flaw is indicated; hence it is a great mistake in our law-books to use such words as "feloniously, maliciously, with **intent** to do grievous bodily harm, **intent** to deceive, **false** pretences, or perjury." Such matters, though the motive is indeed all-important, **cannot** be **known** to a human judge, who is therefore incompetent to punish them, and wrong in attempting it.

27. The **evasion** of such **laws** is usually by simply denying the **intention**; explanation being unnecessary, or if given the actions being attributed to folly, temporary insanity, fear, or any other ground for discordance between the actions and intentions.

28. Equity, justice, or good faith proscribes all deceit, and enjoins the faithful **performance** of contracts or agreements. **Law** provides a material **remedy** to compensate for a material **wrong,** hence there is the following difference between **Law** and **Equity**:

29. Suppose Brown agrees to sell Jones a property, but subsequently (disliking the bargain) were to refuse to **convey** it to him. Jones might either go to **law** about it and **sue** Brown for **breach of contract**; or, on the other hand, he might file a bill in **Equity** and apply for a **specific performance** of the contract. In the

former **case** he would get **damages** for breach of contract, but would **not** get the **property.** In the **latter** case he would get the property but no damages.

30. The existing **inequalities** of **social** position and property cannot be brought within human law any more than the luck or well-directed labour which bestowed or created them; there is no reason, however, why they should not be altered if the alteration could be made without doing wrong to individuals; the fact that they bear heavily on any individual is in itself no argument at all; if backed by **proof** that the aforesaid individual had **deserved** better things and not his present lot; they **would then** amount to an argument against the justice of God's providence in forming man's circumstances and fixing his lot.

31. There are **three sources** of perfect **rights**: Nature, Contract, and Law; and human violence is exerted to obviate the injuries arising from their transgression, in three ways—

(*a*) **In self-defence to repel present injury;**
(*b*) **To compel reparation for past injury;**
(*c*) **As deterrent to prevent future injury.**

32. Personal violence is only permitted to **individuals** in civil society to preserve their persons or property **immediately, all** steps for future security being left to the civil power.

33. The law requires you to have the **same** regard for the transgressor as for yourself, if therefore the means you adopt for self-defence will do him a greater injury than he seeks to do you, you should **submit** to be the **sufferer**; a slight attempt to injure you does not therefore place the transgressor's life at your disposal.

34. The practical **limit** is a matter of conventional

agreement in all civilized society, namely, that the injury you may legally inflict in **self-defence** shall **not exceed** the severest which the **law** could have **awarded** had the assailant succeeded in his attempt.

35. Defence of **life** or limb is held at law to warrant **taking** the assailant's **life**, but even then only when pushed to the last extremity for immediate safety; excess under excitement or fear is excused if not followed up by deliberate cruelty: these laws have been held to apply even between near domestic relations, so jealous is the law in protecting evil-doers.

36. When an **injury** has **been** committed it may be viewed as a **civil wrong**, *i.e.* on the question how far **reparation** can be made, and the injured party replaced **in statu quo**; or it may be tried as a **crime**, and thus made the subject of **punishment** to prevent its repetition. Suppose, for instance, you agreed with parties that they should do certain work, and they, having received advances for it, neglected to perform it; you may file a suit at civil law and get damages for breach of contract; or you may prosecute them for obtaining money under false pretences, but in this latter case your action is almost sure to fail, as you would have to prove each man's **intent** to **defraud** at the time he signed the agreement.

37. In order to **obtain reparation** for an injury, the **claimant** must not be himself in fault; moreover he must prefer his claim **within** a **reasonable time** after the injury has occurred: otherwise the demand is barred as **stale** or estopped by lapse of time. Restitution in **specie** is the rule, and this may be enforced by the civil power, but not privately.

38. What makes an injury a **crime** is the guilty knowledge or wilfulness in its perpetration.

39. Punishments are adjusted rather with respect

to their experienced efficacy than to the nice measure of individual depravity. The efficacy of a punishment depends entirely on the **speed** and **certainty** with which it follows the offence. (No. 19.)

40. Blackstone's theory of referring all crimes and injuries to the State is at fault in the case of a **theft,** where the State suffers *nil*, the property merely changing hands.

41. To warrant **severe punishment,** the evil must be great which would result to the community from the repetition of such offences; there must for all punishment be an **antecedent** and known **responsibility** combined with power in the **agent** of commanding his own actions. Only extreme necessity is held to warrant the imposition of such terrible punishments as death to a sentinel for sleeping at his post.

42. Of injuries against self, **suicide** is only punished on account of the great and **irremediable** injury the suicide does to himself.

43. Of injuries against **God,** man is no judge, and punishments are cautiously applied, never in fact for duties of **absolute** performance, only to enforce outward reverence or to suppress open **irreverence,** propagation of downright idolatry, open worship of confessedly evil spirits under the notion that they are such, human sacrifices, open and wilful profanity.

44. The three **functions** of government are the **legislative,** the **executive,** and the **judicial.** The functions of the **Legislature** are to **ascertain** and generally **define** the **rights** and **obligations** of the whole body of the State. The duties of the **judicial** power are to **interpret** and **apply** the acts of the Legislature to each separate case as it arises. The **executive** duties may be summed up as the actual administration of violence, whether in execution of the laws or for the defence of the realm.

45. The essence of **sovereignty** consists in possession of the supreme **executive** power. The Sovereign is legally irresponsible in **all respects.** Therefore at law might is right, and a revolution is only punishable if unsuccessful.

46. There are three simple forms of government, namely, monarchy, aristocracy, and a republic; in the **third** case only is there a representation of the mass.

47. Law of nations. The distinction between international law and politics is that **politics** refer rather to the science of civil prudence or **ethics** (No. 10) than to **law.** There is also a distinction between **international** law and **public** law; the former referring to the relations which subsist between nations, whereas the latter includes the internal **organization** of states, with the rights and duties consequent thereon.

48. Every **state** possesses certain **rights** recognized by the law of nations; they possess these rights **as** states, and the rights are supposed to result from the law of nature and not from the law of nations: of these rights security is one, and independence is another; but on the whole these rights cannot be clearly defined because states are apt to take what they can, and if they assume it successfully it becomes a legal right (No. 45); a third right is **equality**: a fourth, **property.**

49. The **laws of a nation** affect and apply to all **property** within its territory, all **residents** whether native or foreign, all **contracts** made and **acts** done within it; these laws are recognized by foreign states so far as they do not prejudice the independence and rights of citizens belonging to other nations: foreign claims may be investigated and foreign judgments **may** be (not **must** be) permitted execution.

50. A **contract** if valid at the place where it was made is valid elsewhere.

51. Monarchs enjoying regal honours take the **precedence** of those not enjoying such, and yield the precedence to emperors and kings. The usage of the **alternat** is now in force, the first being originally drawn by lot.

52. With regard to the **rights** of **nations** it will be perceived that there is a vast injustice done under the ruling principle that might **is** right at law. For instance, one kingdom for selfish ends forces **itself** and its commerce on a peaceable harmless nation, whose laws and customs are most contrary, and who wish to be unmolested by the intercourse; in the attempt to prove their **possession** *i. e.* sole and exclusive right to **their own territory** by getting rid of these turbulent foreigners according to their own laws and customs (Nos. 24, 48, 49, 54), blood is shed, and this is taken up by the encroaching kingdom as a **casus belli**, the innocent nation becomes most unjustly and wrongfully (but perfectly **legally**) conquered and attached to the possessions of that kingdom which is the more experienced in doing violence.

53. The third right of nations is **equality**, but the interests of the first Christian settler have been ruled to be weightier than those of the savages in barbarous nations (which at once does away with the equality).

54. The fourth right of nations is the right of **property**, including their original territory, possessions, and properties, acquired by just means or successful violence.

55. A **treaty** is **concluded** by the minister and **ratified** by the **state**; the power of ratification is generally reserved, but no state should withhold it except for a very powerful reason, such as that the minister had not carried out his instructions.

56. There are six kinds of **war**, perfect, imperfect, civil, national, offensive, and defensive. **Perfect war**

implies nation against nation; **imperfect** war is limited as to time, place, or persons or things, as in 1798.

National war is when the authorities undertake a perfect war according to the political organization of the nation.

Civil war is that between the citizens (cives) of the same state.

A war is **offensive** or **defensive** to those who respectively gave or received the first blow.

57. Declaration of war must (by the law of nations) precede commencement of hostilities. The **declaration of war** renders **void** all **commercial** contracts between the belligerent subjects.

58. Private captures on the high seas do **not** belong to the **captors**, but are condemned as **droit** of the Admiralty. A **prisoner** of war is entitled to protection and good usage (whatever that may be interpreted to mean), but **may** be strictly **confined.**

59. Exchange of **prisoners**, on condition of non-service for a time, has always been usual; but exchange unconditionally never till the Russian campaign.

60. If the **right of search** for hostile stores be withstood the concealed property is forfeited; this does not affect **neutral** property on board an enemy's ship. Public buildings, churches, depositories of works of art are held sacred, but only as long as common consent chooses to do so. **Neutral vessels**, under an enemy's convoy, are doubtful capture; in fact, perfect neutrality is impossible to practise, and the attempt offensive to both the belligerent parties.

61. The **sanctions** of the law of nations are **reprisals**; that is, (*a*) the positive seizing of persons or things to compel a state to fulfil its obligations; (*b*) **general** reprisals, when an injured state authorizes its subjects to take the persons and property of the

injurious state; (*c*) **special** reprisals, when letters of marque are granted to individuals in time of peace: these are now disused.

62. Any nation, in virtue of its independence, has a right to **commence war** when it sees fit, and is held entitled to all benefits and subject to all the obligations which the law of **nature** imposes. (The flaw here is that the very fact of **war** is **unnatural** to good, and is itself **evil.** Moreover, it is a matter of ever-varying opinion what the law of nature **does** impose where the aim is to injure and destroy one another as badly as they can invent the means of doing.)

63. A **seizure,** at first **equivocal,** may **become** civil **embargo** if the matter terminates in reconciliation. It may, on the other hand, become a hostile **aggression** in case of subsequent hostilities, the law in both cases having a retroactive effect.

64. Laws may be established by **custom** when the matter has been so long such that the memory of man extendeth not to the contrary. Laws may also be established by **precedent,** on the record, that is, of similar past cases; or they may be simply passed by the **Legislature,** and **made** law.

65. The **law** of England is divided into public and private law. The **sovereignty** is lodged at present in the **three branches** of legislature, which constitute Parliament, namely, King, Lords, and Commons.

66. The **operations** of the **sovereign** power relate to six subjects,—justice, defence, social economy, foreign relations, finance, religion.

67. **Justice**—" suum cuique tribuere "—both legislative and administrative, makes, confirms, abrogates, repeals, restrains, enlarges, revives, and expounds, all manner of **laws.**

68. English **jurisprudence** does not consist entirely

of Parliamentary laws, since "use of old" has come to be respected as law; because the power of legislation was not originally vested in government; moreover, the interpretations of actual Parliamentary laws have come to be accepted themselves as law.

69. The **law of England** may therefore be considered as a system framed with reference to certain principles, which principles are **rights** as far as those who owe allegiance to the law are concerned. These rights are divided into Class A, **private** rights, protection, liberty of person, security, enjoyment of property. Class B, **political** rights, as the franchise, right of petitioning, right to arms, self-defence.

70. Offences against the law may be **both wrongs** (or injuries) **and crimes** at the same time, in which case both satisfaction and punishment are enforced.

71. Compounding a felony or an information, is **itself** a **crime** under special statute: not so with a **wrong**, which always admits of being privately adjusted; this is technically termed **accord and satisfaction**; or it may be referred to an **arbitrator**, who then sits as a **domestic** forum.

72. The **administration of law** may be exercised judicially or ministerially: the judicial ministration is exercised by the **judicatory**, a body vested with the judicial authority by the Crown or supreme power; its authority extends to all cases of **alleged** infraction of **legal rights**; the alleged infraction **must** be controverted as a **fact**, otherwise the judicatory has **no** jurisdiction.

73. A **controversy** may involve questions of **law** or of **facts**, or both: the **judges** point out the law, and decide cases where facts are proved or unquestioned; the **jury** decide those where facts are questioned. The **jury** have two courses open to them; either they may

form a legal opinion on the evidence, as to whether the complainant or the opponent has made out his case; or they may find merely the **facts** as "proven," leaving to the judge the onus of drawing conclusions from the facts.

74. The **jury** are presided over by a **judge**; a person once declared **innocent** by a jury in a criminal controversy, **cannot** be tried **again** on the same count. He may be convicted by the jury, on the other hand, and this judgment may be reversed on a **writ of error** by which he appeals from an inferior to a superior tribunal, which on reviewal can take cognizance only of notorious defect in regard to **law**; the **facts** cannot be disturbed.

75. The **admissibility** or otherwise of **evidence**, and the competency of witnesses, belong to the judge's province: this holds good also in India, but the laws of tenure and inheritance give way to the national Hindu or Muhammedan law. The right of legislation is vested in the Governor-General, only he is limited in the exercise of it by the **interests** of the State, the prerogative of the Crown, and the Mutiny Act.

76. There are **three** superior **courts** of **common law**, Queen's Bench, Common Pleas, and Exchequer; the Queen's judges sit in each of these, they are five in number, and are styled **justices** in the two former courts, **barons** in the latter; the presidents being styled Chief Justices in the two former courts, and Chief Baron in the Court of Exchequer.

77. The original **distribution of work** in these three courts was as follows: crime, and the sovereign rights, dignity, and functions, excepting revenue alone, belonged to the Court of **Queen's Bench**; on the other hand, civil suits between subject and subject (communia placita), belonged to the Court of **Common**

Pleas; again, matters relating to the Royal revenue belonged to the Court of Exchequer.

78. The jurisdiction of the Court of **Common Pleas** alone now remains unaltered, the other courts having so far invaded its province that they extend to cases of **recovery** of goods, **damages,** *i. e.* redress for **breach of contract** or **like** injuries.

79. In legal **controversies** without jury, the parties still go to Westminster Hall; also in cases involving questions of **facts** to be **afterwards** decided by a jury, the portions involving only points of **law** may be previously decided by the courts of Westminster; that is, they decide in what **shape** the trial shall be conducted; but after the controversy has assumed its final shape, the jurisdiction of these courts passes into circuit (itinerant justices).

80. The **judges** of the three superior courts (No. 76) are appointed by the **Crown**; they do not vacate on the demise of the king, only on address of both Houses of Parliament. They are prohibited from **selling** justice, delaying or staying delivery of judgment even at the King's command, or delivering their opinion on any case beforehand.

81. Inferior to these Crown judges there are others with local jurisdiction, derived from traditional or common law, or from Act of Parliament: most of the ancient local tribunals have fallen into disuse and decay. The renowned **County Court** is an offspring of Teutonic times, and is **confined** to **cases** of less value than **£20.** The **sheriff** presides over it.

82. Justices of the Peace share the judicial power to a certain extent, and **can** decide trifling cases singly; they have a joint jurisdiction when sitting together in the **Court** of **Quarter Sessions** of the Peace, which court is competent to decide cases of injury with implied

violence (**trespass**), or of any crime which is not **capital** nor such as is punishable by **transportation** beyond the seas.

83. A **coroner** is **chosen** for **life** by the county **freeholders**; his duty is to direct his jury on law points, and to assist them in coming to a conclusion in cases of sudden death.

84. The extraordinary judicatories are the **House of Lords** and the **Court of Chancery**.

85. Chancery was intended to supply the wants and correct the rigour of the positive law; it administers a peculiar branch of law styled **equity**, which, though it in no case subverts the **principles** of common law, yet exerts discretion in the carrying out of measures.

86. Certain matters can be better adjudicated by **Chancery** than by law: such are matters of **account**, questions of **dower** and **tithes**; **partitions** can be less expensively effected; Chancery was intended to afford **relief**; it acts upon the **individual**, not the thing; in pursuit of its objects it can restrain even legal rights: it affords relief in cases of accident, mistake, or suffering from another's fraud, especially in **contracts**. Besides the difference before adverted to between law and chancery in a case of breach of contract (No. 29), there is another peculiarity, viz. that a court of equity regards **penalties** incurred for neglect of money payments as **securities** to be relieved against on payment of the money and interest within a **reasonable** time, whereas at law they are considered to be **forfeited** once for all in default.

87. A **Court** of **Chancery** can compel the **discovery** of facts on oath by the **defendant**: it is a judge **both** of law and of facts (73).

88. There are **three chancery courts**, namely, that in which the **Chancellor** presides: 2, the **Master of**

the Rolls' Court; 3, that of the three **Vice-Chancellors,** of whom the senior is Vice-Chancellor of England.

89. The **House of Lords** is the **supreme** appellate **jurisdiction** in the kingdom: out of session certain members are summoned specially to form a **Lord High Steward's Court**; their jurisdiction extends criminally to cases of high treason and felony committed by peers and queens, dowager or consort.

90. What is called **voluntary jurisdiction** of judges relates to certain ministerial duties executed over and above their judicial ones; the functions of the **Consistory** and **Prerogative** courts in granting **probate** of wills, and administration of effects of intestates are styled **voluntary**, but obviously with impropriety.

91. The **forms** to be observed in **legislation** are regulated by **custom** of Parliament: every law in its original condition is a **Bill**: either House may originate a **Bill**, and before it can become **law** it has to pass in both Houses, and is read four times, viz. first, second, and third readings, and the motion "that this Bill do now pass:" between the second and third readings, the Bill is proposed clause by clause, and alterations may be made; clauses may even be added **at** the third reading.

92. The above forms having been complied with, the **Bill** is submitted to the Queen, who can give or withhold her consent. In case of bills of grace or pardon, the rights of peers, election and qualification of members, raising, &c., of monies, the measures cannot be initiated **indiscriminately**; the first generally originates with the **Crown**, the second with the House of Lords, and the latter from the House of Commons.

93. The chief public wrongs or **crimes** which are artificial or **not self-evident** are **misprision** of treason;

that is connivance at treason; **præmunire**, which applies to such as appeal to Rome, refuse to consecrate, assert that either or both Houses have legislative authority without the Queen; who send a subject prisoner beyond the seas; who knowingly solemnize a marriage with any of the descendants of George II. forbidden to marry; who side with a pretender (unless he be successful).

94. Perjury consists of swearing in a judicial proceeding **wilfully, absolutely,** and **falsely,** with **deliberation** and intention on some point **material** to the matter in question. So that one who has committed perjury must be ready to explain, if properly called upon to do so, that either he did not swear **wilfully,** did not **fully** mean what he said, **fancied** in a certain sense what he swore might perchance be figuratively not untrue, or that he had not **full** time for deliberation, had not fully intended and chosen **freely** and uninfluenced to swear it, did not think his oath was material, &c.; or simply that he was **frightened** and did not mean what he said; otherwise he cannot safely commit perjury.

95. Compounding felony, that is forbearing information, is punishable as felony itself.

96. The **private law** of England is composed of various systems blended, and is **general** in its obligation as **traditional** and **statute** law, or **particular** in its obligation as **customary, ecclesiastical, and maritime** law. The common law of England possesses over foreign systems the great advantage of being flexible, and so adaptable to the requirements of an advancing nation. The **sources** of common law are **judicial opinions,** and certain **text writers.**

97. Judicial opinions are contained in reports of the trial, defence, decision, and its reasons, on past cases:

also in records of proceedings containing **only** the judgment.

98. **Judicial opinions** are of two kinds, namely, **decisions** and **dicta.**

99. A **decision** is the **conclusion to** which the judge comes on the case before him, and his **decision forms** a **prĕcĕdent** which will govern similar future **cases. Prĕcĕdents** may, however, be **overruled** when contrary to reason or common experience.

100. A **rule** is a point **decided** or laid down by competent authority, and partakes of the nature of a **maxim.**

101. A past **decision** operates upon a similar case by furnishing a **rule** and by showing the reason for it.

102. **Judicial dicta** are **opinions** of judges expressed irrelevant to the case in question, or at least not containing the necessary grounds of the judgment pronounced; **dicta** have not the value of **decisions.**

103. The **text-books** of eminent lawyers, such as Lord **Coke,** have great authority as guides.

104. **Statute law** consists of **Acts of Parliament.** Of these there are two kinds; **Public Acts,** enacting with regard from the Sovereign to sheriffs, lords of manors, the whole spirituality, and to trade in general. **Private Acts,** concerning only particular species, things, persons, or places.

105. **Statutes** may **introduce** a new law, declare the old law (declaratory), supply its defects (remedial), or affix penalties (penal). A **statute** can be repealed or altered only by a statute; the **intent** of a statute will prevail over the **literal** meaning; the **parts** are to be construed **together;** statutes on the **same** subject to be construed **together; no** one built upon **exclusively** to the traversing of another; **remedial** statutes are to be interpreted **liberally; penal** statutes strictly; as also

are statutes unfriendly to the **liberties** of the subject, or imposing **charges.**

106. Statutes conferring powers derogatory to the rights of private property must be interpreted **strictly,** so must **Private Acts** of Parliament conferring new and **extraordinary** powers, or creating new **jurisdictions**; **statutes** are not to be construed so as to **admit** of **absurd** consequences (a limitation which at once renders all the rest perfectly superfluous, and might be more briefly expressed by saying that statutes are not to be construed at all).

107. The law **statutes** commence with Henry III., and are called **vetera statuta** down to Edward II.: all subsequent ones are called **nova statuta**; the earliest are in Latin, the first in French being 51 of Henry III.; the statutes are in French and Latin mixed from thence down to 33 Henry VI., which is the last statute wholly in Latin; the English began after the fourth year of Henry VII.

108. Customary law is composed of certain immemorial and local customs; such are **gavelkind, borough English,** and customs of various manors: for a **custom** to be good at law it must have been held so long that "the memory of man knoweth not to the contrary"; it must have been in **continuous** use, acquiesced in, **reasonable,** certain, **compulsory,** and mutually consistent with other customs. Hence no one need acquiesce in a customary law who thinks it unreasonable; on the other hand, anyone may establish a custom legally, **provided he succeeds** in intimidating opposition, and compelling acquiescence for time sufficient to introduce those who know nothing to the contrary, within the sphere of its action.

109. In the application of **private law** a distinction is made between **ceded** and **conquered** territory. The

process, as regards a foreigner in England, must be according to our law; thus a man may be arrested for debt, or, in Equity, upon a writ **ne exeat regno,** although at the place where he contracted the debt he might not have been liable to imprisonment.

110. It is of the very nature of **law** that it **creates rights**, and provides **remedies** for **wrongs.**

111. Rights of **individuals** relate only to **person** or **property**; **rights of persons** arise from **mutual relaticns**, such as marriage, parentage, and guardianship; or from **service.**

112. As regards **marriage**, the parties must **not** be, under the **canonical disabilities** of pre-contract, consanguinity, affinity, or impotency; nor under the **legal disabilities** of subsisting marriage, want of age, want of parent or guardian's consent, or want of reason.

113. Parties under **legal disabilities** cannot **even** contract the **marriage**, it is void ab initio; the marriage of parties under **canonical disabilities** is **voidable** merely, that is, it can be **made** void by proceedings in an Ecclesiastical Court, but subsists pending the Court's decision. Marriage of parties within the prohibited degrees of consanguinity or affinity is absolutely void.

114. The **Ecclesiastical** Courts cannot **dissolve** a marriage after the death of either party when the ground of dissolution existed previous to marriage, such as consanguinity, and did not arise subsequently, as impotence. The effect of the dissolution of a marriage consists in abrogation of the marriage with its incidents, and bastardizing the issue; this is called **divorce a vinculo matrimonii.**

115. In case of **clearly established adultery** or **cruelty** the Ecclesiastical Court may grant **a divorce a mensa et thoro,** by which the wife is entitled to an

allowance and separate maintenance, the amount of which is to be settled by the ecclesiastical judge.

116. **A husband** is bound to provide his wife **with necessaries**, and to pay her debts for **necessaries**, unless she have **eloped** and be **living in adultery**; he is also liable for all her debts contracted before marriage, nor can she be sued without his consent.

117. **Parents** may **whip** their children moderately, and may delegate that power to tutors; should a tutor, however, fail to obtain such power or consent, it appears that he might be tried for an indecent assault at law.

118. **Service** of **menial servants** engaged without mention of time is supposed to extend to **one year**, with the **option** of **terminating** the engagement on either side by **one month's** warning or one month's wages.

119. A **master** is generally **answerable** for his servant's conduct **if** acting according to his orders; in this case usual permission is held tantamount to an order: in some cases a master is held answerable for the results of his servant's **negligence**.

120. **Partnerships** or agreements between several parties, to share the profits of their joint undertakings in some concern, whether as dormant, nominal, or acting partners, **if created** by **law**, are called **corporations**.

121. The law ascribes immutability to **corporations**, whether **sole** or **aggregate**. A bishop or a parson is a **corporation sole**, a dean and chapter is a **corporation aggregate**.

122. **Corporations** may be **ecclesiastical** or **lay**; the East India Company and South Sea Company were **trading corporations**. **Corporations** must be created either by the King's prerogative, or by Act of Parliament expressed or implied. A **corporation** must have

a name, perpetual succession, and a common seal; corporations sue and are sued under their corporate name; make binding by-laws; being invisible they appear by attorney, can commit no crime, nor be subject to personal injury; having no soul they are not liable to ecclesiastical censure, and are usually **visited** to ensure their ends being duly fulfilled.

123. Corporations may be dissolved by Act of Parliament; on dissolution, the lands, &c., revert to the founder, donors, or their heirs.

124. Rights of property differ according as the property is **real** or **personal.**

125. Real property consists of lands, tenements, and hereditaments, in fact **fixtures** generally.

126. Lands include soil, produce, woods, mines, and edifices (a **lake** should be described as **land covered** with water, **not** as **water**). **Tenements** include that which is held subject to the superior right of another.

127. Hereditaments include all that may be inherited; they are twofold, corporeal and incorporeal.

128. Corporeal hereditaments include all under the nomen generalissimum. Of **incorporeal hereditaments** there are ten kinds, namely:—

(1) **Advowson,** or right of presentation to a benefice;
(2) **Tithes;**
(3) **Common,** or piscary, turbary (turf), estobers (or necessary wood), from another's ground;
(4) **Right of way;**
(5) **Offices and taking fees;**
(6) **Dignities;**
(7) **Franchises;**
(8) **Corodies,** or right of sustenance;
(9) **Annuities;**
(10) **Rents.**

129. It is necessary that every **transfer of land** should be made in **public.** An **estate** is either **freehold** or

less than freehold. **Freehold estates** are either of inheritance or not of inheritance; those of **inheritance** are (1) estates in fee **simple**; (2) estates in fee **base**; (3) estates in fee **tail**, or conditional. **Freehold** estates, **not** of inheritance, are estates **tail** after possibility of issue extinct, (2) for life, (3) by courtesy of England, (4) dower.

130. Estates **less** than **freehold** are (1) estates for years, (2) at will, (3) year by year, (4) by sufferance.

131. A **tenant** in **fee simple** is he who is a tenant of the King; "that hath lands, tenements, and hereditaments, to himself and to his heirs for ever."

132. A **fee base** is such a fee as hath a qualification subjoined thereto—the owner, while his estate lasts, has all the privileges of a tenant in fee simple.

133. A **fee tail** is a fee conditional, restrained to some particular heirs exclusively.

134. A **tenant** by **courtesy of England** is the **life estate** to which the husband is entitled after the death of his wife.

135. To **terminate** a **tenancy**, if there be no express agreement on the subject, and no immemorial usage, half a year's notice to quit must be given, so that the half year may terminate at the season the tenancy commenced.

136. An estate **at sufferance** is when one **comes into** possession of land by lawful **title**, and keeps it after **without** title.

137. **Conditions** are void if impossible when created, if becoming so by act of God, or by the act of their maker, if contrary to law, or repugnant to the nature of the estate.

138. **Mortgages** are the most ordinary kind of estates upon **condition.**

139. **Estates** considered with reference to **time**, are

either in **possession**, **remainder**, or reversion; when the **interest** actually **resides** in the owner, it is an estate in **possession**.

140. When an **estate** is **limited** to be taken after another estate has **determined**, according to original limitation, nature, and extent, it is called an estate **in remainder**.

141. Remainders are **vested**, or **contingent**; if they have a **fixed** and immediate **right** of future enjoyment, they are **vested**. So long as the **future** estate has no capacity of taking effect in **possession** on the determination of the particular estate (140), it is a **contingent remainder**.

142. An estate **in reversion** is the residue of an estate left by the grantor, to commence in possession after the **determination** of some particular estate granted out by him.

143. Real property may be **acquired** legally in various modes, namely, (1) title by **possession**, (2) **descent**, (3) **purchase**.

144. Mere **possession** without title may by **negligence** ripen into a perfect and indefeasible **right**.

145. Title by **descent** is when the title vests in a man by the single operation of law.

146. Purchase is where the title vests in a man by **his own act** or agreement, conjointly with, or independently of, such operation of law (145).

147. There are **seven rules** of **descent**.

(1) **Inheritances descend but never ascend.**
(2) **Male takes the precedence of female.**
(3) **The eldest male inherits if there are males, but if there is no male all the females inherit together.**
(4) **Lineal descendants fully represent their ancestor.**
(5) **Failing issue the inheritance passes to collateral branches of the same blood as the original purchaser, subject to the preceding rules: the other rules are similar.**

148. **Forfeiture of lands** is consequent upon

(1) **Crimes and misdemeanors**;
(2) **Alienation, contrary to law**;
(3) **Non-performance of conditions**;
(4) **Waste**;
(5) **Breach of copyhold customs**;
(6) **Bankruptcy**;
(7) **Striking in the presence of a principal court of justice.**

149. **Title by prescription** is when a right has been enjoyed for thirty years unchallenged, after which period it cannot be defeated; after sixty years it is absolute and indefeasible, unless it be shown that some writing of permission was originally given.

150. Property is **acquired** by a **deed of conveyance.**

151. **Conveyances** to and by **idiots, lunatics,** and **infants,** are **not** necessarily void, but **voidable**; that is, should reason be recovered or majority attained, option is given in the matter. The conveyance or contract of a **married woman,** while married, is void. Persons attainted of **treason, felony,** or **præmunire,** are incapacitated from conveying in future.

152. **Possession** is the proper object of every **conveyance.** A **deed of conveyance** must be written or printed on paper or parchment, sealed and delivered; signature is **not necessary**: of the various species of deeds some are effectual at common law; such are feoffment, gift, grant, lease, assignment, release; and some derive their operation from the **statute of leases**; such are lease, release, and wills.

153. **Personal property,** or **goods** and **chattels,** includes all species of possession, not freehold, and not capable of descending to the **heir-at-law,** but which vest on demise in the **executors** or administrators.

154. **Chattels** are divided into **chattels real,** such

as terms for years, the next presentation to the Church, and **chattels personal,** which are properly things **movable,** animals, household stuff, **money,** and corn; all of which are therefore **personal property.**

155. Grants or **gifts** of chattels are the right of transferring the possession of them.

156. Earnest money. No contract for the sale of goods to a value of 10*l.* (ten pounds) or upwards shall hold good except **part** of the said goods be received by the purchaser, or some **earnest** money be given.

157. In **hiring,** the hirer acquires a temporary property, subject to an implied condition to use it with moderation; the owner or **lender retains** his reversionary interest, and acquires a new property in the price or reward.

158. Actions. Civil actions are divided into real, personal, and mixed. When the action addresses itself to things directly, **actio in rem,** seeking the recovery of real property, it is a **real action.**

159. Personal actions are those brought **in personam,** and seek generally pecuniary recompense or satisfaction.

160. Mixed actions partake of the nature of both real and personal actions.

161. Debt, covenant, or where one claims damages for breach of promise, come under **real** actions.

162. Detenue is an action for recovery of detained goods.

163. Trespass is an injury with violence, actual or implied, where the injury is direct, and on the person or tangible property of the plaintiff.

164. Trespass **upon the case,** is when a party seeks damages for any wrong to which **covenant,** or **trespass** will not apply (161, 163).

165. Two kinds of **trespass upon the case,** are well

known, namely, **assumpsit,** for breach of promise **not** under **seal**; the promise may be either actual or **implied,** the law always implying a promise to do what the party is legally bound to perform.

166. Trover and **replevin: trover** is the action usually adopted to try **disputed** questions of **property,** such as goods and chattels.

167. Replevin is an action to try the **legality** of a **distress** for rent. In **form** the party seeks **damages** for illegal taking and detaining of his goods and chattels.

168. The following are the more important stages of **personal** actions.

Action commences with a **writ of summons** desiring the party to **appear** at the court of law which issued the summons, at the instance of **plaintiff.**

169. Thereupon the defendant "**enters an appearance**" and the plaintiff proceeds to specify the ground of his complaint in a formal document which is communicated to the defendant, and the preparation of which document requires much **professional** skill and knowledge.

170. To this declaration the defendant either **pleads** or **demurs.**

171. In **demurring,** the defendant objects to the declaration made by the plaintiff (No. 169) as **insufficient on legal grounds**; that is, as inadequate, **however true,** to support the charge founded on its evidence.

172. By the act of **demurring** the defendant **precludes** himself from **denying** the **truth** of such facts as have been sufficiently pleaded.

173. The law requires the opposite party to **deny** the allegation of him who **demurs,** and thus the parties are said to be **at issue**; an issue at law being a **controversy,** is triable by the judges.

174. Instead of **demurring,** however, the defendant may **plead,** or **put in a plea.**

175. Pleas may be of various kinds; for instance, a plea may consist of an **exception** to the remedy sought; in denying the **jurisdiction** of the court, or **sufficiency** of the plaintiff, being an **alien**; or may aver other facts, which, without affecting the real merits of the case, impugn simply its conformity with law. Pleas may be **to the action**, and either deny the truth of the plaintiff's allegations, or avoid their legal effect by setting forth other facts, which give a different complexion.

176. The **defendant**, in short, may either **traverse**, or confess and **avoid** his opponent's statements. If he **traverses**, the plaintiff must **join issue**, and the issue being then a question of **facts**, is triable by jury (No. 73).

177. The **various stages** of the **procedure** are as below:—

First, the **plaintiff** makes a—	To which the **defendant** answers by a—
1. Declaration;	2. Plea;
3. Replication;	4. Rejoinder;
5. Sur-rejoinder;	6. Rebutter;
7. Sur-rebutter.	

By these means the trial may be prolonged until one party or the other **traverses** (176), and issue is joined, whereupon the trial proceeds. Skill in **logic** is often required to separate questions of **facts** from questions of law.

178. In conclusion, if a **good man** be one who tries to **serve** and **please the innocent,** it will be seen that the **law** is only applicable to **evil** men, that is, it attempts most imperfectly to prevent those who seek to serve and please **themselves** at the expense of others; from injuring others in the pursuit of their selfish aims. It is **imperfect** because cunning can always invent ways of doing injury outside the **letter** of the law;

whereas the **spirit** of the law, though much talked about, is impossible to apply safely by punishments or violence of any other kind; for it deals with the offender's **motives**, which are **sècret** and **most dangerous** for a human judge to attempt to touch, lest he perpetrate a gross **injustice** under the name of **law.**

179. That **law**, and especially the law of **custom**, may be not only separate from, but **antagonistic to**, real good is also evident on illustration: a man, for instance, who attempted to sell his goods and give them to the gentle, meek, and **poor** in spirit, would most likely find himself the subject of a committee *de lunatico inquirendo* to prove him incapable of conducting his own affairs with discretion; if he attempted to "**wash the saints' feet**," or perform any similar act of affectionate humility, he might think himself lucky should he escape an action for an indecent assault. Again, should he try to give the preference to the meek, gentle, and lowly, over the proud, manly, and violent, in the bestowal of his services, he would soon be driven to learn that established usage forms a law which he dares not contravene, and to the tyranny of which he had better submit until the time comes when societies are **rightly grouped** into association in a world where each is "gathered to his own."

INDEX.

C.

E.

F.

G.

H.

M.

N.

O.

Q.

R.

S.